



**MAJOR COST DRIVERS OF MOTOR VEHICLE CRASHES INVOLVING
AIR FORCE MILITARY PERSONNEL AND THE INFLUENCE OF THE
MILITARY ENVIRONMENT**

THESIS

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AFIT/GCA/ENV/11-S01

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Abstract

Motor vehicle crashes (MVCs) involving USAF military personnel when off duty/off base are a critical concern for the Department of Defense (DoD), due to potential impact on mission readiness. In addition, the cost of MVCs places excessive financial burden on the USAF budget, apart from productivity loss and negative emotional consequences on the victims. In particular, total injury cost was \$ 356M, based on 2010 CY dollars. Determining the underlying factors leading to MVCs is crucial to establishing effective preventive measures to mitigate the negative consequences of MVCs.

This thesis applied categorical data and multiple regression analyses on (AFSC) historical data collected over 22 years. Specifically, analysis focused on MVCs in which (USAF) military personnel were involved when operating PMVs off duty/off base. Categorical data analysis revealed that USAF males with Company grade officers and those aged 17-20 years were more vulnerable to fatal MVCs, while Airman group, males 20-25 years old, were associated with the majority of MVCs. Moreover, MVCs most often occur between 0900-1400 & 1900-2400 hours during travel to or from work, while the most risky and hazardous time is 0500-0800 & 0100-0400. Impaired driving was not investigated by blood alcohol test in the greater part of MVCs, however, there was strong evidence that alcohol involvement correlated with the crash severity causing death and disability among service members. Additionally, alcohol was significantly associated with the Airman and Senior NCO rank groups while impaired driving increased during the invasions of

Iraq and Afghanistan as well as the Gulf War (FY 2001-2007 and FY 1990-1991) accordingly. Environmental conditions, characterized by periods with high workload and operational tempo, resulted in greater volume and severity of MVCs. Alcohol involvement in MVCs was peaked during those periods, with Field Grade Officers affected significantly by those environmental conditions. Worth noting is that the Airman group was the least impacted by the pace of operations with respect to their involvement in MVCs. Ultimately, human and environmental factors, such as demographics and political-societal conditions resulted in a regression model for the volume of MVCs, exhibiting an R^2 Adjusted in excess of 0.99. The variables are numerical and were from the most predictive, while the model passed all the necessary tests for model accuracy.

AFIT/GCA/ENV/11-S01

To my Children

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MAJOR COST DRIVERS OF MOTOR VEHICLE CRASHES INVOLVING AIR FORCE MILITARY PERSONNEL AND THE INFLUENCE OF THE MILITARY ENVIRONMENT

I. Introduction

Background

Road transportation is one of the most important factors of economic growth. Globally, people have to be on the road many times per day in order to go to school, work or to any other activity of their daily routine. In other words, by making the movement of people, material and goods easier, it improves access to work, education and develops financial markets. For these reason governments globally spend and invest a lot of their annual budget to expand road networks to increase the availability of goods and services, employment and general economic prosperity.

Unfortunately, the emphasis on increasing the efficiency of road transportation systems has led to a significant loss of people's lives and health because of the absence of safe driving habits by people and the insufficient attention by the organizations charged with safety oversight (WHO, 2010). Morbidity and mortality due to injuries have always existed in the past but their recognition as a public health problem is a phenomenon of the mid-twentieth century (WHO, 2001:2). Considering the significance of the problem, a week after World Health Day, 14 April 2004, the

United Nations General Assembly, passed a resolution calling for greater attention and recourses to be directed towards road safety efforts (WHO, 2010:xi).

According to the World Health Organization (WHO, World report statistics), 1.2 million people are killed on roads every year and 20 to 50 million suffer non-fatal injuries. Over 90% of the world's fatalities occur in low and middle income countries which have only 48% of the world's registered vehicles (WHO, 2008). The World Health Organization also predicts that road traffic injuries are expected to reach 2.4 million by the year 2030, rising from the 9th cause of death in 2004 to the 5th cause of death by 2030. This is ahead of others serious problems such as diabetes mellitus, hypertensive heart disease, HIV/AIDS, and tuberculosis (WHO, 2008:29-30).

In 1949, Smeed was the first to establish the relationship between fatality rates and motorization, by explaining how the global increase of motor vehicles due to socioeconomic changes and the requirement to travel increases people's exposure to road traffic risk (Smeed, 1949). In particular, motor vehicle accidents have been characterized worldwide as a "hidden epidemic" which affects all fields of society (PAHO, 2004).

The scale of road traffic accidents and injuries varies considerably according to geographical region. For example, in August 2003, the General Assembly of the United Nations pointed out that in 2000 more than a third (435,000) of the global road car accidents and deaths occurred in South East Asia. In the same year, Africa had the highest road traffic rate death, 28 deaths per 100,000 populations (WHO, 2003).

In the United States (US), motor vehicles are the main forms of transportation, providing an unparalleled degree of mobility. However, deaths and injuries resulting from MVCs are the leading cause of death and lost years of productive life for people 4 through 33 years old (NHTSA, 2004). In particular, according to the Department of

Transportation “Traffic Safety Facts Annual Report” issued by the National Highway Traffic Safety Administration (NHTSA), in 2004, 41,821 people were killed and 3,189,000 were injured, in the 6,394,000 estimated police reported MVCs (NHTSA, 2004).

It is worth pointing out that traffic fatalities have been decreasing since 1972, with a sharp decline since 2005. Figure 1, depicts that MVCs have decreased by about 22% from 2005 to 2009 (NHTSA, 2010:12). However, the fatality problem persists considering that, 33,808 people were killed in MVCs in the U.S. in 2009 (NHTSA, 2010).

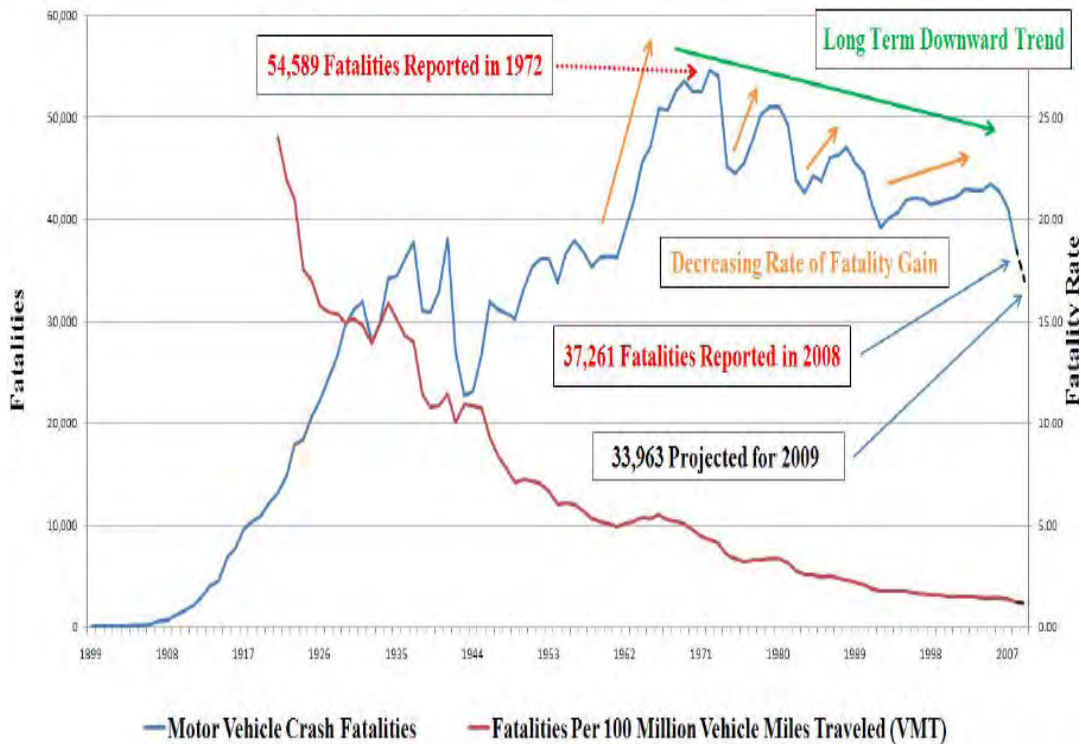


Figure 1. Motor Vehicle Crash Fatalities and Rates (per 100 Million Vehicle Miles Traveled) 1899-2009, courtesy of NHTSA (NHTSA, 2010)

Alcohol use, pace of operations, stress, fatigue, speeding, failure to wear a safety belt, age and gender have all been associated with greater frequency and severity of motor vehicle injuries. The fact that alcohol was involved in a significant

proportion of crashes led to the enactment of blood alcohol concentration (BAC) limits for driving in all 50 States of 0.08g/dL. For example, in 2008 in the US, the alcohol impaired driving fatality rate was 0.40 fatalities per 100 million vehicle miles traveled (VMT) (NHTSA, 2009).

Although both genders and all ages drink and drive, researchers tend to agree that the typical drunk driver is the younger man, aged 18 to 29. Unfortunately for the military, this is the demographic which constitutes a large percentage of military personnel (AFPC, 2010).

Apart from alcohol impaired driving, MVCs are complex events and a major source of death and suffering in society. MVCs cause more death and injuries than wars, acts of terrorism, and disasters and are the leading cause of post traumatic stress disorder (PTSD) (Blanchart and Hicklin, 1997). The negative consequences affect not only US society, but all branches of the US military. In particular, MVCs are the leading cause of death and disability among active duty military personnel, with the greatest impact seen in the Army, but also the Marine Corps (Karl, et al., 2010).

According to the Air Force Safety Center (AFSC), MVC fatality rates appear to be increased during the “101 Critical Days of Summer”, between Memorial Day weekend and Labor Day. For example, in this period during FY 2007-2009, of the 58 total fatalities, 36 of them were due to private MVCs. This increasing rate during the traditional summer vacation time explains the fact that people travel more often for leisure and off –duty activities. However, the consequence of increased road traffic exposure correlates directly with increased numbers of car accidents. This emphasizes the fact that MVCs and their negative consequences are some of the most critical issues DoD has faced for many years parallel to other operational issues.

Recent research, based on AFSC data, has focused on the factors that affect MVCs involving USAF personnel and the number of lost days. In particular, for FY1988-2007, 12,403 Private Motor Vehicle (PMV) off base accidents involving AF military personnel were reported, in which 1,104 people died. Of this group, 242 people were completely or partially disabled, and the 12,088 people with various types of injuries, resulted in 152,252 lost workdays for an estimated total cost of about \$417 million (Markopoulos, 2009).

Even though the fatality rate has decreased over the years, the risk for MVCs is still very high and is influenced by a combination of many factors. This thesis considers the analysis of those factors very important to the entire process from identifying the problem to implementing an intervention policy relative to MVCs. According to WHO this process includes several steps (WHO, 2010):

- (i) Gathering information of demographic characteristics of the victims as well as geographical features and the circumstances of the accident.
- (ii) Identification of the factors that maximize the risk of injury or disability.
- (iii) Determine what measures should be taken to prevent MVCs.
- (iv) Implementation of such measures.

In the WHO report, the Haddon matrix is reported as an analytical tool to help identify all factors associated with a MVC. In this matrix the risk factors are distinguished in three categories: human, equipment (e.g., vehicle, etc.), and environment as the methodology this thesis will employ to analyze MVCs (WHO, 2010:2-24).

The most traditional approach in the analysis of road traffic risk considers the importance of the above factors and investigates them separately, since each one plays a specific role and contributes disproportionately in a potential MVC (WHO, 2010:2-25).

While the human factor is the most important, environment and equipment, as the second and third factors, contribute significantly in MVCs. Figure 2 depicts the transportation system as it can be observed visually with respect to the nature and complexity of the interactions of its elements. This is imperative for decision makers understanding of the traffic network system so as to organize and implement the most effective safety measures.

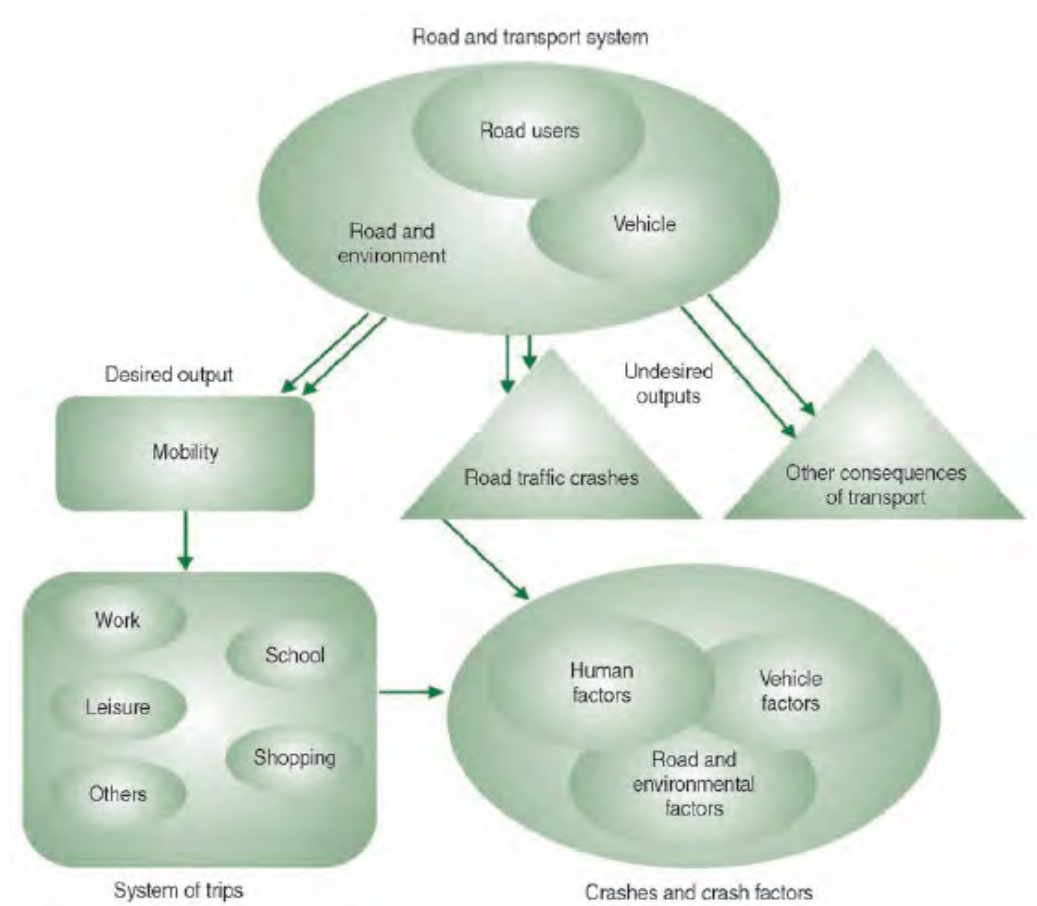


Figure 2 Risk Factors for Road Traffic Injury Prevention, *courtesy of WHO* (WHO, 2010:2-26)

As far as the military is concerned, the human factor in MVCs is critical because military life is stressful enough with moving every few years and all the activities that keep service members away from home. Moreover, operations tempo in terms of deployment and temporary duty assignments add additional levels of stress and fatigue on military members and their families. Such stress and fatigue is exacerbated during times of war. Considering that MVCs affect the victims' lives, their families and friends, as well as both the military and society in general, appropriate measures should be taken towards the development of a prevention strategy.

In addition, considering that safety is a fundamental human right, traffic safety must be identified as an essential part of any transport policy. Even if the majority of positive changes relative to road user behavior are a result of traffic safety laws, the need for societal support is necessary because laws by themselves cannot always change behavior (WHO, 2001:38). WHO estimates that by 2020, the total number of MVC fatalities and injuries will increase globally by 65%, if communities within the relative organizations do not take safety measures towards accident-reduction (WHO, 2004:3).

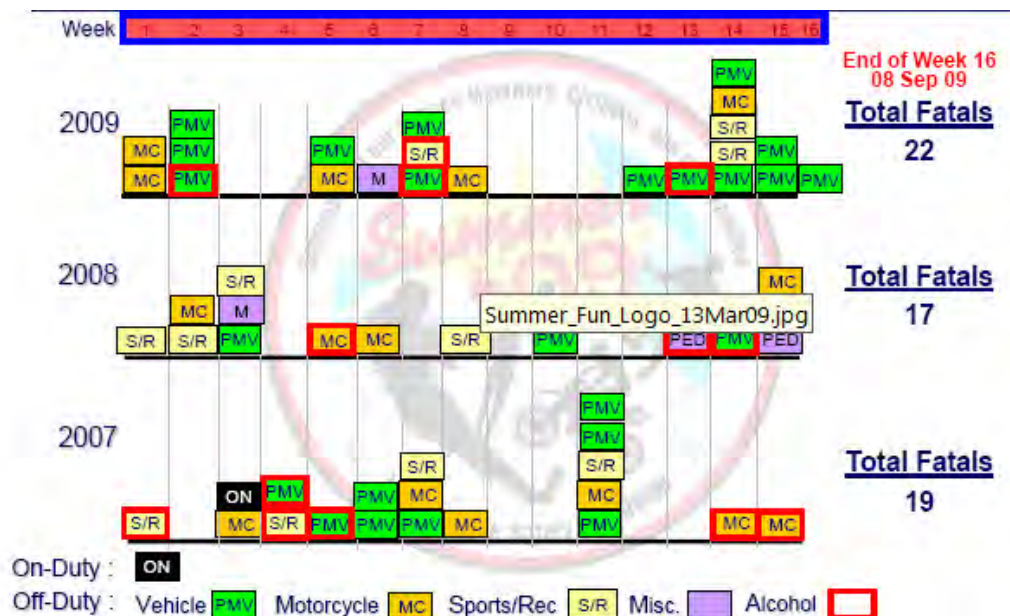
The USAF issues many regulations and has put into practice several intervention programs, out of awareness of the direct emotional and negative consequences on MVC victims, as well as the productivity loss due to workplace disruption and the economic burden for medical and rehabilitation services. The "101 Critical Days of Summer" campaign is one of the intervention programs that the USAF employs towards the establishment of more safe driving/riding habits.

Through the use of AFSC historical data, this thesis will try to provide data analysis that can support the USAF intervention efforts.

Problem Statement

The direct, negative consequences on service members involved in MVCs dramatically affect the USAF. For example, according to the AFSC, during the critical days of summer period 2007 through 2009, MVCs were the leading cause of death of USAF personnel. Despite the USAF intervention efforts, the fatality rate remains high and MVCs persist as the leading cause of service member deaths every year. Taking into account education and training investments, as well as compromised operational readiness and productivity of the USAF, the negative outcome of this loss is considerable. Table 1, depicts the ground fatality summary for summer period 2007 through Sep 2009 and indicates that PMV crashes are the leading cause of death among service members.

Table 1. US Air Force Security Center 2009 Critical Days Fatality Summary (AFSC, 2009)



Both, number of fatalities and fatality rates show that MVCs represent a considerable problem for the USAF. In view of this critical issue, the goal is to decrease as much as possible the fatal and severe MVCs, below 29 fatalities for FY 2010, as depicted in Figure 3, and their consequential negative impact.

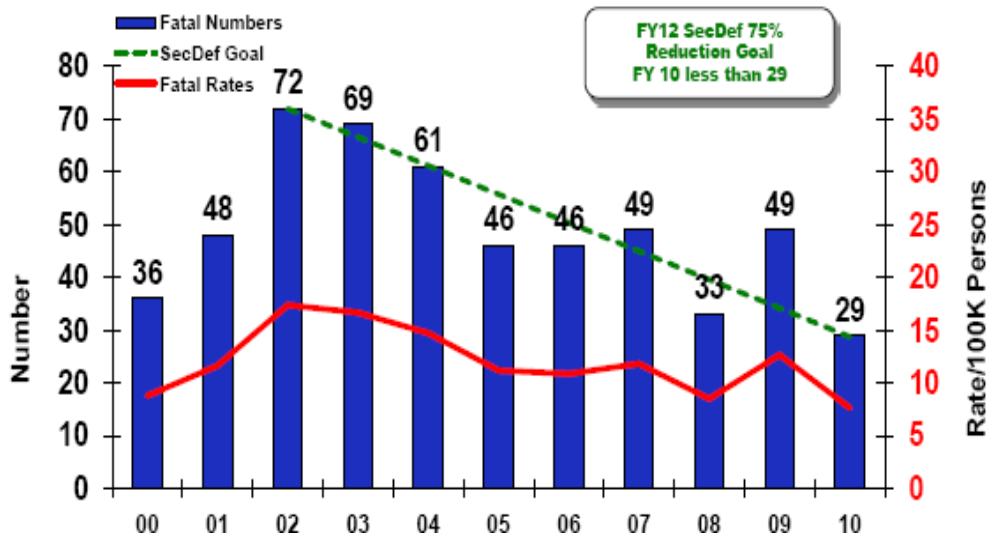


Figure 3. USAF Off-Duty PMV Fatalities thru FY 10

The harmful impact to operations and readiness and, in general, AF productivity, cause considerable economic cost to the society apart from the direct emotional cost to the victims and their families.

Purpose and Rationale

Previous research based on specific analysis approach and methodology, identified factors that influence MVCs and the loss of workdays. However following an extensive research of the data, this thesis will conduct a different analysis approach and will address military-related factors that might also influence the severity of MVCs. Furthermore, information incorporated in the data, such as FY and alcohol involvement, as well as regression analysis techniques should be utilized to extend the predictability and the outcome of the research.

The main purpose of this thesis is to identify the conditions under which USAF military personnel are involved in MVCs, and how these conditions interact with environmental influences that affect frequency and severity of crashes. Both are major cost drivers and sources of great financial burden to the USAF budget. This thesis uses the AFSC data of off duty/off base MVCs in which USAF military personnel are involved as drivers and applies categorical data analysis and regression analysis to address the following research questions:

1. Whether the factors of gender, age and rank of USAF military personnel affect the severity and risk of MVCs.
2. Whether the time of day influences the severity and risk of MVCs.
3. Whether the type of vehicle (four-wheeled (4W), or two-wheeled (2W)) affects the severity and risk of MVCs.
4. Whether alcohol involvement is associated with the severity and risk of MVCs.
5. Whether seatbelt usage by USAF military personnel is associated with the severity a MVC.
6. Whether the gender, age or rank of USAF military personnel is associated with alcohol involvement at the time of a MVC.
7. Whether FY (pace of operations) associated with the severity and the risk of MVCs.
8. Whether FY operations tempo (war-peace) is associated with the severity and risk of MVCs.
9. Whether rank and alcohol involvement is associated with operations tempo influencing the climate for a MVC.
10. What factors influence the volume of MVCs affecting the USAF's direct cost.

Scope and Limitations

The following assumptions have been made to reconcile AFSC data and identified limitations prior to the methodology application:

1. The initial data includes MVC events from 11 October 1987 to 1 May 2010. As using entire fiscal years is more efficient for this study analysis, the methodology was applied to MVCs observations reported between FY 1988 and FY 2009 only.
2. The study focuses only on USAF military personnel, so any other unrelated historical data is excluded for this analysis
3. Given the fact that the research focuses on off-base private MVCs of USAF military personnel, on base/ on duty MVCs were excluded.
4. This thesis concentrates solely on USAF military personnel as operators of motor vehicles, not as passengers
5. Furthermore, the research considers when “time of the day= 0” as missing data. Any other approach inflates other results.
6. Literature recommends the use of “alcohol involvement”, rather than “BAC”, as a better indicator of impaired driving.
7. The scope of the research is to build a new data base, based on historical data when modeling the frequency of MVCs. Due to the fact that the new database includes only twenty two years of MVC documentation, the analysis will incorporate the entire data set without leaving space for model validation.
8. This thesis removed all data duplicates to prevent the increased risk to inflate or provide biased results. This process also utilized the MVC mishap number assigned for identification.

Preview

This chapter presents the problem and purpose of this thesis, states its policy objectives, defines the research questions, as well as the assumptions/limitations that have been made in order to reconcile the AFSC data.

Chapter II reviews both the current literature of MVCs as well as a previous work on this research topic. Chapter III will present in detail the research strategy utilized to provide information from the data, states preliminary assumptions and sets up the analytical methodology with the outcome of the analysis demonstrated in

Chapter IV. Finally, Chapter V outlines the conclusions of this study and recommendations for further research.

II. Literature Review

Motor Vehicle Crashes – Problem Identification

The first reported motor vehicle accident was in New York City on 30 May 1896, and the first reported pedestrian death was in London on 17 August of the same year. By 1997, the cumulative road traffic fatalities had reached 25 million. It is estimated that in 2002, a total of 1.18 million people lost their lives to MVCs with an average of 3,242 fatalities per day. Moreover, an estimated 20 to 50 million people had been injured or remained disabled, in road accidents, around the world. (WHO, 2004:11). Figure 4, depicts the proportion of worldwide road traffic fatalities in 2002, accounts for almost 23% of all deaths and is more than fatalities due to war.

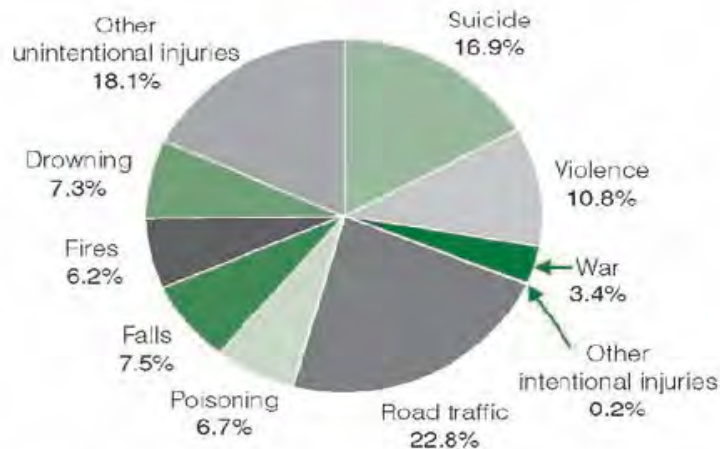


Figure 4: Distribution of global injury mortality by cause *courtesy of WHO* (WHO, 2006:11)

The frequency of MVC occurrence depends on region and country. Although, the global amount of road traffic fatalities rises, a downward trend can be seen for high income countries while an upward trend persists for low income countries. It is remarkable that higher MVC rates are associated with low and middle income countries which together account for 90% of all traffic fatalities in 2002. On the contrary, since the decade of the 1960's, MVCs in high income countries have decreased. Of particular note, the fatality rate in North America for the period FY 1975 to 1998 declined by 27%, while in Canada alone the statistical was 63% (WHO, 2002:13).

The relative proportions of worldwide road traffic injury in 2002 are depicted in Figure 5 below. Globally, the higher percentages are represented in Africa while the U.S. is at the lower end of the spectrum.

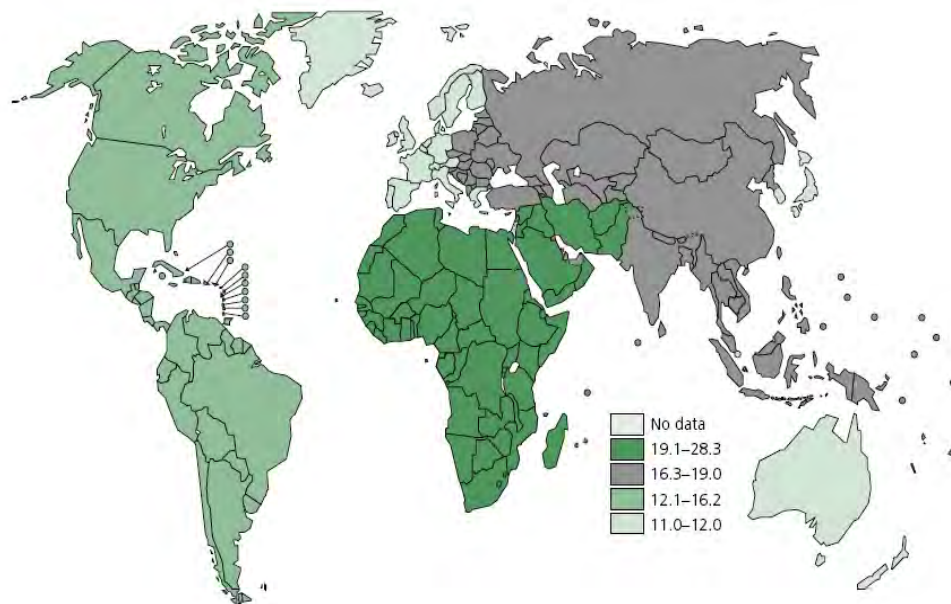


Figure 5: Road traffic injury mortality rates (per 100,000 populations) in WHO regions, 2002, *courtesy of WHO*, (WHO, 2004:11).

Motor Vehicle Crashes – Public Health Alarm

Unfortunately, according to World Health Organization studies, traffic fatality rates will be increase dramatically in the future. More specifically, from FY 1990 to 2020, MVCs will become the sixth most significant cause of death in the world, with road traffic fatalities projected to increase from 0.99 to 2.34 million yearly (WHO, 2004:12). Furthermore, it is forecasted that traffic fatalities in low income countries will increase an average of 80% while decreasing approximately 30% in high income countries.

Motor Vehicle Crashes in the United States

Per the US Department of Transportation, National Highway Traffic Safety Administration, in 2002 MVCs were the leading cause of death for people between 3 and 33 years old when approximately 1 of every 55 deaths was due to MVCs. In that year, 44,065 people lost their lives due to traffic crashes and the death rate was 15.2 deaths per 100,000 (NHTSA:2005).

Since 1975, the most deadliest days have traditionally been July 4, July 3, December 23 and December 24. Figure 6 shows the high number of traffic fatalities on those days for the period of FY 1975 through FY 2002.

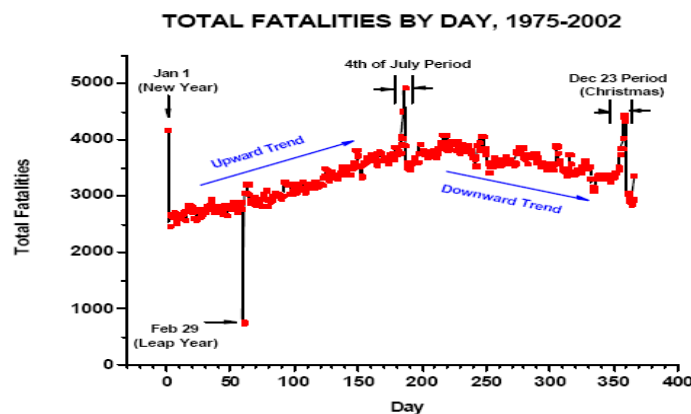


Figure 6: Crash Fatalities by Day 1975-2002, courtesy of NHTSA, (NHTSA, 2005:11)

Chapter I, defined risk factors related to MVCs in three broad categories, human, environment and vehicle. These factors are examined separately in the traditional risk analysis approach due to their disproportional influences in MVCs. (WHO, 2010: 2:25).

The complicated road network is one of the places millions of people are killed every year. This system requires multiple breakdown analyses in order to include the interactions of every factor that take place when a MVC occur. In light of this extensive approach, it is essential to make a reference in the multiple factors of a road traffic injury, in order to have a sufficient understanding of MVCs in the road traffic network.

The basic nature of MVCs analysis is to take into account not only the subordinate factors but also everything else related to them, including the government's prevention measures. Considered in this framework, (WHO) research identified the risk factors related to traffic injuries under the following four categories: (WHO, 2010: 2:27).

Factors Influencing exposure to risk

People use the road traffic network to go to school, work and other social activities. As societal and economic changes force people to travel more often, their exposure to risk increases at an exponential rate. This category includes both economic and demographic factors. In addition, land use, the nature of high speed motorized traffic combined with insufficient attention and decisions relative to speed limits, road layout and design are critical parameters increasing the risk of MVCs.

Factors Influencing crash involvement

Speed of travel is the main influence factor in this category as it impacts both the risk of the driver and the consequences of the crash. Apart from that, a series of other factors influence the choice for aggressive driving. For example, while alcohol and youth age are the most well-known, vehicular power, road and network quality also contribute significantly to a MVC. Moreover, inadequate visibility, due to environmental factors, and driver fatigue are relevant, particularly, in MVCs that occur in long-distance driving. However, alcohol consumption and excessive speed are the two of the most critical factors of this category.

Factors Influencing crash severity

It is a well known fact that technology of both the private and public vehicles has improved considerably. Safety measures and engineering advantages found in vehicles in high income countries decrease the negative consequences of MVCs. Unfortunately, these advances neither standard nor available in low income countries. For that reason the absence of such safety measures results in the most severe car accidents. Secondly, roadside objects decrease driver visibility and affect the way drivers interact with the road system. This is also critical and may be the cause of many MVCs as well.

Factors Influencing post-crash outcome of injuries

The critical factors that influence decisions with respect to potential death include access to immediate assistance, emergency responders and hospital proximity.

Figure 7 demonstrates the Haddon Matrix, a systematic and methodical tool that is very helpful for analyzing the related risk factors at the time a MVC by categorizing risk factors before, during and after the crash with respect to the person, environment and vehicle-equipment (WHO, 2010:2-24).

The Haddon matrix

		FACTORS		
PHASE		HUMAN	VEHICLES AND EQUIPMENT	ENVIRONMENT
Pre-crash	Crash prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities
Crash	Injury prevention during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash protective design	Crash-protective roadside objects
Post-crash	Life sustaining	First-aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Figure 7: Haddon Matrix, courtesy of WHO, (WHO, 2010)

This thesis, considering both the scientific methodology of the majority of studies in the field of MVCs, and the analysis of this research, will be based on the breakdown structure into three categories for risk factors in a potential MVC. This is the basis of the Haddon Matrix discussed in detail later in this chapter. The three main broad categories of risk factors are as follow:

1. Human Factors
2. Environment Factors and
3. Vehicle-Equipment Factors

Deviations that occur in sub- categories both individually and combined compose the suitable conditions under which MVCs occur.

Human Factors

Although MVCs appear to be in decline due to driving laws, improvements in the road structure and better cars, traffic fatalities rates are still high and primarily

because of human error. Unfortunately, people become accustomed to driving in ways that a single error can cost them their lives.

The possibility of human error is a function of many characteristics that include age, gender, blood alcohol concentration, speed, and failure to wear a safety belt or other equipment. Some other features that have been identified as influential MVC factors related to human error include lack of education, emotional problems, instability in relationships or work (Simon and Corbet, 1996) and other stressors that may result from exposure to war (Richter, 1991; Valent, 2004:03-10).

Age

According to the NHTSA, MVCs are the leading cause of death for people 15 to 20 years old in the United States. In fact, in 2007, young drivers represented 9% of the US population, 6% of the licensed drivers and 19% of the traffic fatalities (NHTSA, 2009). Figure 8, shows that MVCs fatalities accounts for 35% of deaths of young people and is considered one of the leading cause of deaths.

Leading Causes of Death for Teens

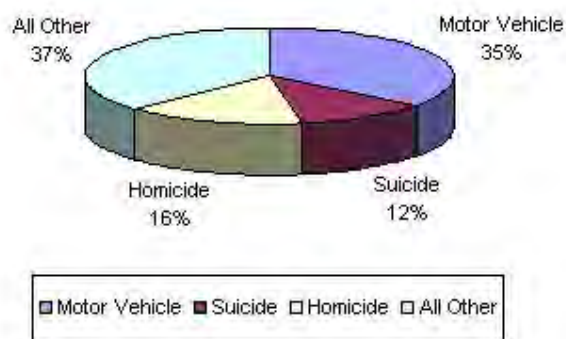


Figure 8: Leading Causes of Death for Teen Drivers, *courtesy of NHTSA, (NHTSA, 2010)*

In fact, teen drivers are more vulnerable to be involved in a MVC due to their immaturity and inexperience. These characteristics, combined with impaired-distracted driving and excessive speed, exacerbate the risk of such involvement.

Furthermore, the distractions caused by technology (e.g., cell phone use, texting) contribute to their exposure to road traffic risk. As a result, due to their poor judgment, both their decision making and consideration of consequences are compromised with respect to road traffic risk and potential death.

Risk taking behavior is easily manifested and influenced by frustration or anger with other road users or conditions. In particular, the influences of alcohol that incapacitate judgment, dangerous overtaking attempts to impress passengers, speeding to decrease trip time are all sources of risky driving behavior. However, young people who demonstrate risky driving habits, experience a sense of euphoria by rationalizing their actions in parallel with overconfidence, ignorance or impaired ability to recognize hazardous conditions. It is believed that teen drivers represent this attitude because, due to their young age, they are trying to take the control of their lives by looking for independence. In that way they show resistance to adult authority and to societal rules. These characteristics, along with their inability to cope with stressful situations, categorize them as the age group that most represents risky driving habits.

Gender

Many studies show that more men are involved in MVCs than women. In particular, young males predominately figure into MVCs due to excessive speed, and impaired, distracted, aggressive driving as demonstrated in Figure 9.

However, recently women have demonstrated driving habits that are trending to minimize the gap between the gender groups. The evidence that female drivers are

more vulnerable to MVCs can be explained by the fact that, in recent years, they use vehicles more often than in the past.

The woman's role in society has evolved so that by using the traffic system more often they expose themselves to increased road traffic risk, consequentially causing higher involvement of females' drivers in road traffic accidents.

Speeding Drivers in Fatal Crashes by Age and Sex, 2008

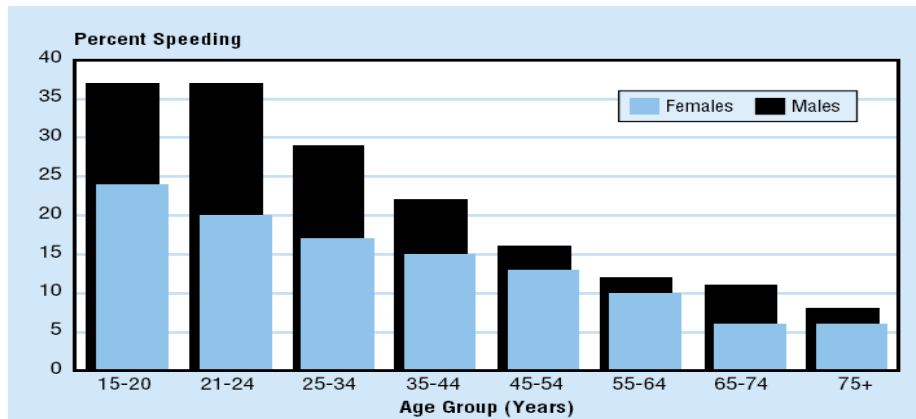


Figure 9: Speeding drivers in fatal crashes by age and sex, *courtesy of NHTSA, (NHTSA, 2008:7)*

On the other hand, according to the National Institute of Health (NIH), there are other arbitrating factors that influence women's involvement in MVCs. In particular, although young females seem to have better safe driving habits than males, young female drivers have more problems to handle a vehicle under extraordinary conditions and control situations. For example, the likelihood for female drivers to lose control on slippery roads is greater than for a male driver (NIH, 2008).

Excessive Speed-Aggressive & Distracted Driving and Other Violations

In the literature for traffic safety, speed is one of the main factors for MVCs when exceeding the stated speed limit or driving too fast under specific and dangerous traffic conditions. Speed increases the possibility of MVCs because it decreases the amount of the reaction time. Moreover, speed elevates the severity, and as a

consequence, the potential fatality due to increased forces the human body experiences at impact. That means the faster the speed of a vehicle, the greater the risk of an accident.

It is worth pointing out that people know the risk but they ignore the dangers, believing they will be able to control their cars. For that reason, governments have determined the maximum speed limits for safe travel on the nation's road traffic network. According to NHTSA'S Fatality Analysis Reporting System (FARS), both the frequency of fatal crashes and the percentage of total crashes that are speed related have almost remained constant from 1990 to 2006. However, both are considerably high in frequency, ranging between 11,000 and 13,000 crashes per year and 30-33% of total reported volume (NHTSA, 2010). As shown in figure 10 below, although MVCs demonstrate a downward trend the proportion of speed related car accidents remains unchanged.

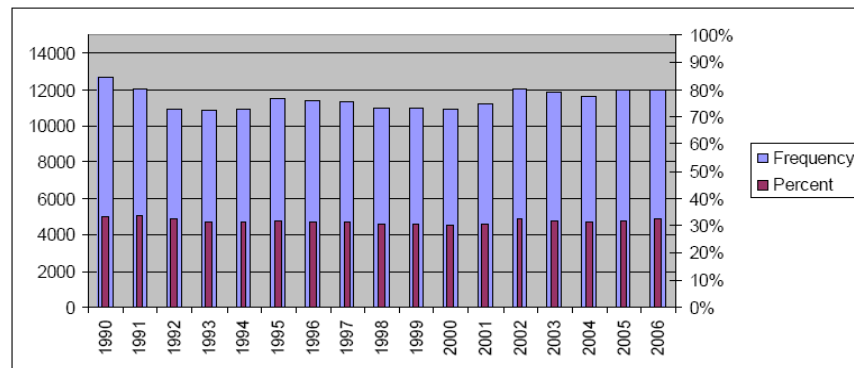


Figure 10. Frequency of fatal crashes and percentage of total crashes that are speeding related, *courtesy of NHTSA*, (NHTSA, 2010)

Excessive speed translates into following too close, offensively changing lanes too often and general failure to obey traffic signals. These traffic violations influence the risk for a driver to be involved in a MVC.

In addition, distracted driving is another reason many people die or are injured in MVCs. The types of distracted driving are defined as following by the NHTSA:

“Distracted driving is any non-driving activity a person engages in that has the potential to distract him or her from the primary task of driving and increase the risk of crashing.”

There are three types of distractions (NHTSA, 2010):

- (i) Visual, when drivers take their eyes off the road
- (ii) Manual, when drivers take their hands off the steering wheel
- (iii) Cognitive, when drivers don't concentrate on what they are doing.

Examples of distractions while driving include cell phones, eating and drinking, talking to other passengers, reading such as maps and GPS, and changing the radio station. While all endanger lives, texting, by far, presents the greatest risk involving multiple distractions. Specifically in the US, in 2008, 6,000 people died in MVCs due to some type of distraction, with 20% of all crashes caused by distracted driving (NHTSA, 2010).

Impaired driving

Alcohol consumption is one of the most important causes of illness and death among people all over the world. According to the WHO (WHO, 2004:1:22), 1.8 million people died due to alcohol worldwide in 2004. Also, alcohol consumption has health and social consequences. The most notorious are substance dependence, chronic diseases, and traumatic outcomes with harmful consequences such as traffic and other accidents that cause death or disability, particularly at young ages.

In addition, inability to cope with other people in the family or at work, demonstrates the harmful consequences of alcohol consumption and the impact to labor productivity and to society as a whole (WHO, 2004:47). The extent, of those

problems depends on the volume of consumption and the individual's drinking habits. Both affect biological functions, by blood alcohol concentration (BAC) levels, that explain the role of alcohol to injury in terms of relative reaction time, cognitive processing, coordination and alertness, and propensity for violent crime and aggressive behavior. As a consequence, alcohol works as depressant to relax the body into an unnatural sense of pleasure and friendliness, harmful consequences related to alcohol abuse. Alcohol is catastrophic with respect to road safety because its consumption, even in small amounts, increases the risk of MVCs by impaired vision, judgment and reaction time, all high risk components (WHO, 2007: xi).

Figure 11, highlights alcohol involvement in fatal crashes in selected countries around the world. In the USA alone about 17,000 people are killed and half a million injured every year in alcohol related MVCs. Moreover, 40% of the total young driving population traffic fatalities are due to alcohol consumption. (WHO, 2007:1-5)

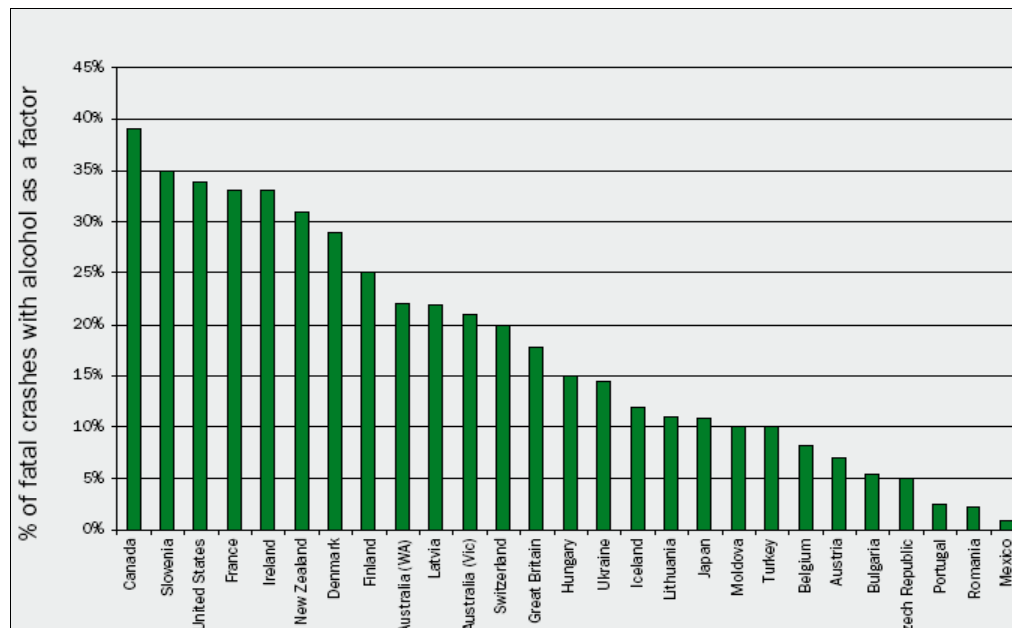


Figure 11. Drink – Driving a factor in fatal crashes 2002--2004 data, courtesy of WHO, (WHO, 2007:1-4)

Furthermore, 16,885 fatalities in alcohol related crashes during 2005 (39% of total traffic fatalities for the year), represent an average of one alcohol related fatality every 31 minutes (NHTSA, 2009). The evidence that alcohol was causally involved in a significant proportion of crashes led to the enactment of blood alcohol concentration (BAC) limits of 0.08g/dL for driving in all 50 states.

Drivers are considered to be alcohol impaired when the BAC level is 0.08g/dl or higher. However, according to the US DOT (NHTSA, Driver Characteristics and Impairment at Various BACs, August 2009) studies, the influence of alcohol at 0.04% BAC is statistically associated with impaired driving. In the US the number of alcohol related fatal crashes has declined in the past two decades. Figure 12 depicts changes between 2007-2008 in the number of alcohol impaired drivers by state and gender.

Changes in the Number of Alcohol-Impaired Drivers in 2008, Compared to 2007, by State and Gender

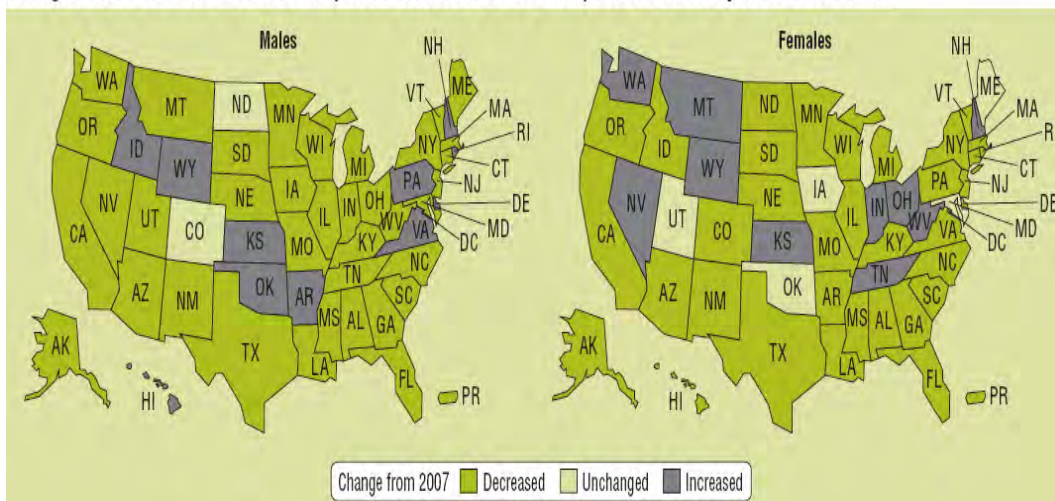


Figure 12. Changes between 2007-2008 in the number of alcohol impaired drivers by state and gender, courtesy of NHTSA, (NHTSA, 2009)

Fatal crashes in the US due to impaired driving demonstrate a steady decline from FY 1982 to FY 1997. Figure 14 below, depicts both the steadily decreasing trend as well as the increasing rate from 2000 after three years of no change.

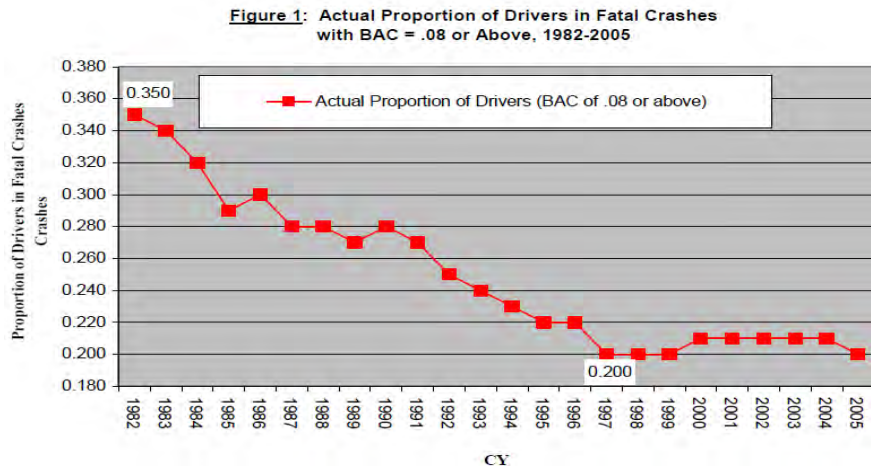


Figure 13: Actual Proportion of Drivers in Fatal Crashes with BAC=0.08 or Above, 1982-2005, courtesy of NHTSA, (NHTSA, 2008)

Over the past two decades, efforts from many organizations in both the public and or private sectors have been made to deter impaired driving. Specifically, alcohol programs and laws in the US express the lack of tolerance against those who drink and drive (NHTSA, 2008: v). That study, claims that the reduction in alcohol related MVCs through FY 1997 and the plateau levels between FY 1997 to FY2005 are due to State legislation actions relative to alcohol related driving.

In summary, alcohol is one of the most critical factors stimulating crash risk and influencing its severity. For that reason this thesis acknowledges the necessity to analytically examine alcohol as risk factor in MVCs, as well as, additional factors such as stress correlated with alcohol consumption.

Alcohol & Stress

Individuals use alcohol to cope with both economic and work related stress, as well as crises in personal relationships. However, high doses of alcohol consumption and stress are correlated with the evidence suggesting that alcohol consumption or abuse is behavior choices to relieve stress. The fact that people are exposed to

stressful situations due to sadness, poor health or daily annoyances is a characteristic of human life.

In many cases, according to the National Sleep Foundation (NSF, 2008), the result of societal and economic pressure and stress is excessive sleepiness related to fatigue and a number of primary sleep disorders. People skip sleep for more productive effort or such extensive access to technology makes it easy to stay awake. For that reason it is estimated that people now sleep 20% less than in the past century. In addition, working at night, or adopting changing work schedules are all reasons for excessive sleepiness affecting the quality of life, productivity and personal relationships.

According to the National Science Foundation 36% of American drive drowsy or fall asleep while driving (NSF, 2008). Unfortunately, driving requires sustained concentration for recognition, judgment calls and reaction to changes in the environment that may cause hazards. This requisite state of alert may be compromised by drivers affected by stress and fatigue resulting in debilitating life consequences.

Military Life - Deployments- Pace of Operations

The main characteristics of military life, such as deployments, operations tempo and other related factors might influence MVCs, endangering service members in their private life. Military life can be very stressful to service members due to frequent assignment changes creating demands in both the work environment and private life that require both flexibility and adjustment. Furthermore, deployments, temporary duty assignments, and training missions compound the stress on military members.

Many researchers argue that work overload is associated with performance. For the military, the work overload can be expressed through the concept of high operations tempo overlapping three military environments: garrison, training and deployment. The term operations tempo refers to the pace of military operations or missions, a concept that exists mostly in a deployed environment (Thomas et al., 2005). Castro and Adler suggest that operations tempo be broken down into three components: daily workload, deployment workload, and training load while taking into account the needs to include overload which occurs when individuals are asked to perform too much within too little time (Castro and Adler, 1999).

In fact, since the end of the Cold War, there has been an issue concerning unanticipated increases in the tempo of operations in the US Forces. The General Accountability Office (GAO), recognizing that deployments had been increased from FY 1990 to FY 1995, concluded that the amount of deployment time of military personnel has increased with adverse affects on readiness (GAO, 1996:1). In fact, there was inequality between the structure of the US forces and mission requirements due to multiple deployments resulting on increased stress of some of U.S. military capabilities. According to the National Defense Research Institute, the number of days away from home has doubled from FY 2001 to 2004 (RAND, 2007:48). For that reason, Congress authorized mandates to compensate for the stress of service members and their families due to deployments, while at the same time, examining efforts for deployment reduction.

Former Secretary of Defense Donald Rumsfeld recognized in December, 2002 the need to rebalance the Forces due to mismatch between the defense strategy and the force structure as well as and the consequential high operations tempo. May, 2004, it was decided that overall troop strength in Iraq would be stabilized at 138,000

(Rumsfeld, 2003).

The need for rebalancing the forces took place by moving people from low demand positions to fill vacancies in high demand positions. In 1998, AF Deputy Chief of Staff Lt Gen Lawrence P. Farrell, Jr., described how the series of expeditionary operations in the 1990s not only impacted those military members directly involved in operations overseas, but also severely affected those members serving stateside (Callander, 1998).

Such facts provide evidence that operations tempo affected the military in terms of readiness and productivity. This is logical since after the Gulf War, and throughout the 1990s, increasing rates of deployments allocated new demands on service members and their families. In particular, during the height of the deployments to Bosnia in the late 1990s, survey results showed that many soldiers who intended to leave the military had reported that deployments had harmed their marriages and the well being of their families (Castro and Adler, 1999). Therefore, it is no coincidence that operations tempo and retention have been correlated since the early 1990s (Castro and Adler 1999). As a consequence the increased desire to separate may have been due to the high operations tempo. Figure 14, displays information relative to the AF military personnel for FY 1988-2009.

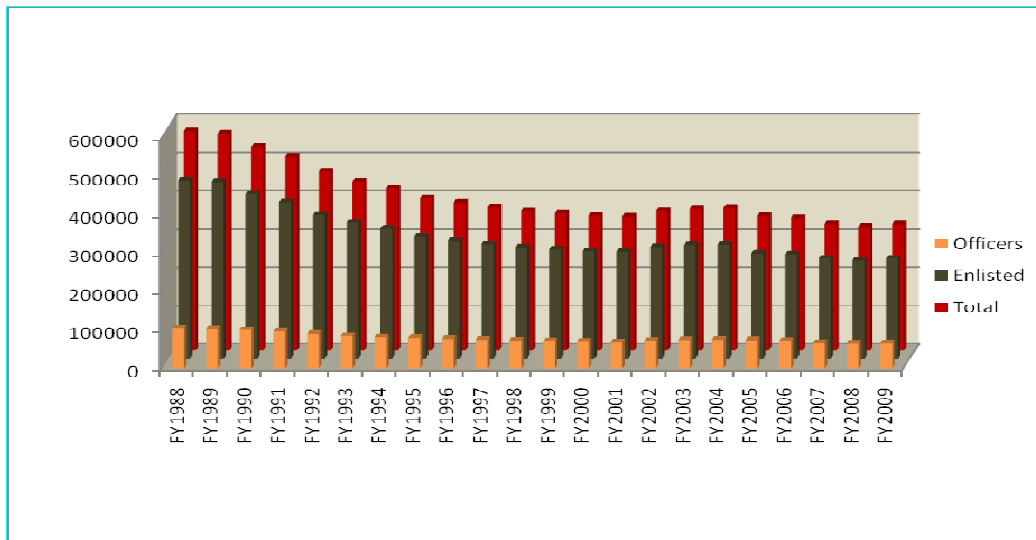


Figure 14. Air Force Active Duty Personnel FY1988-2009, HQ AFPC

The previous paragraphs suggest that the period for the investigation of this thesis, FY 1988 to 2009, influenced the severity and frequency of private MVCs involving USAF personnel. This is important because the analysis of each event should be examined in the context of specific environmental circumstances. In addition, other surveys relevant to this period provide detailed, useful information about operations tempo, stress, and alcohol consumption all factors that affect service members and their families and might explain the conditions under which MVCs occur.

It is argued that military personnel serving during the Gulf War period reported low levels of health-related quality of life. Stressful and traumatic events, such as those encountered during a prompt military deployment response, are associated with a range of unfavorable health effects. Smoking and other unfavorable health behaviors, such as alcohol and drug use, may explain some of the increased physical symptoms reported by Gulf War veterans with Posttraumatic Stress Disorder (PTSD) (Drue et al., 2002:3).

Surveys show that Gulf War veterans have suffered a wide range of health problems since returning from the war. Research suggests that they are not related with any specific syndrome or exposure that might explain post war morbidity. However, they manifest as an increase in injuries and mental health problems, as well as alcohol related disorders and stress (Gregory et al., 2004:26(5)). This morbidity indicator explains the fact that Gulf War veterans demonstrated 50% higher MVC fatality rates than non-deployed veterans (DeBakey et al., 2002:488-534).

The influence of the 1991 Gulf War deployment on fatal MVCs across all military services was investigated by a nested case-control study of fatalities in Gulf War era veterans for the period 1991-1995. This study suggested that demographic and behavioral characteristics of deployed healthy warriors was consistent with the risk profile, such as young age and risky driving habits, equivalent of fatal MVCs. Specifically, individuals who served during periods of ground combat, particularly in infantry, gun crew or seamanship occupations, should be targeted for preventive measures (Hooper et al., 2006:518-525).

Overall concern exists for post deployment health consequences among all US military personnel returning from recent deployment. In recent history, US forces have been occupied in exhaustive combat deployment in Iraq and Afghanistan for more than five years. Epidemiological study in the military cohort deployed in these countries from 2001 to 2006 highlights that specific combat exposures, rather than the deployment itself, significantly affect the onset of symptoms of post traumatic stress disorder following deployment. The unknown and relative instability under which troops have to respond during deployment, in parallel with the complexity of the problems they face, can cause high stress levels and health consequences (Smith, 2008:366–371).

A previous study investigated active components of the US Army between 2004 and 2007 for PTSD, depression, functional impairment, alcohol misuse, and aggressive behavior. It was found that the rates of PTSD and depression after returning from combat ranged from 9 to 31% depending on the level of functional impairment reported. In particular, alcohol abuse, aggressive behavior and morbidity, were present in approximately half of the cases. For that reason it is pointed out that high morbidity with alcohol abuse and aggression highlight the need for comprehensive post deployment screening (Thomas et al., 2010:614-23).

Because the phenomenon has been prevalent since the last decade, the correlation between deployments with high stress levels and alcohol abuse has become a subject of many studies. Therefore, it is important to discriminate how the military community perceives stress differently. By example, women in the military believe the greatest source of stress is being away from family (21.1%), followed by major changes in family such as death or birth (17.0%), increases in workload (15.9%), problems in work relationships (15.7%), and problems with supervisors (13.1%) (Bray et al., 1999:239-256).

For men the most frequent source of stress is being away from family (23.7%), deployment (17.1%), increases in workload (16.6%), financial problems (15.0%), and conflicts between family and military responsibilities (13%) (Bray et al., 1999:239-256). This research, conducted in 1995, found that about one fourth of military personnel used alcohol to cope with stress, while those who experienced high stress levels at work were almost 1.4% more likely to use alcohol than others.

Combat deployment associated with alcohol use and alcohol related problems was confirmed by the study Alcohol Use and Alcohol Related Problems Before and After Combat Deployment (Jacobson et al., 2008:663-675). In particular, Reserves

and National Guard members who reported recent combat exposures are at increased risk of heavy weekly drinking, binge drinking and alcohol related problems.

This association also exists during peacekeeping deployments. US soldiers who deployed from Germany to areas in the former Yugoslavia were surveyed regarding their alcohol use and reaction to various stressors. Results indicated that 14.2% of the medical unit and 14.6% of the border patrol unit responded they were trying to moderate pressure by drinking more alcohol than usual. Those soldiers reporting an increase in alcohol use also reported experiencing high stress levels from boredom, isolation, separation from spouse and unit leadership than those who reported no alcohol increase (Adler and Bartone, 1995).

Alcohol misuse or heavy drinking is associated with significant health problems and increased risk of injury and death. A previous study of Air National Guard and Air Force reserve personnel revealed a high prevalence for binge drinking, while 4% of participants reported that they drove after they had five or more drinks and 9% were passengers in a vehicle with a heavy drinking driver (Vander Weg, 2006).

Alcohol use has other negative health and social consequences. For example, active duty military personnel, from all services, who are heavy drinkers were more likely to report not being promoted, get into altercations, fail to meet performance standards, drink and driving, and experience other criminal justice problems (Stahre et al., 2009:208-217).

As a consequence alcohol related morbidity and mortality is one of the most important health problems in the U.S., but particularly in the US forces. In fact, military service members consume more alcohol than civilians. As far as the USAF is concerned, 283 deaths were reported for 1990. Injuries accounted for 73% of all

deaths, and MVCs accounted for 31% of total mortality, with 23% attributable to alcohol (Stout et al., 1990:220-223).

This problem takes on critical significance because people try to cope with stress, boredom, and loneliness as indicated by the previous research. The majority of these studies reveal that youth, male gender and lack of education is the profile of the person most vulnerable to alcohol consumption and high involvement in MVCs and injuries. For that reason, this demographic should likely be the focus of preventive measures.

According to the AF personnel demographics in March 2011, young males were the dominant population group. Important demographic data include:

- (i) 330,606 individuals are on active duty (65,101 officers and 265,505 enlisted personnel)
- (ii) The average age of the officer force is 35 while for enlisted Airmen, it is 29
- (iii) Of the force, 38% are below the age of 26
- (iv) 44% of enlisted Airmen are below 26 versus 13% of officers
- (v) 19.1% of the force are women

Apart from the stress, deployments, and the fact that the military has a considerable number of young males, alcohol consumption is influenced also by the workplace culture and alcohol availability. People who work together cultivate mutual beliefs that can influence alcohol use. For example, heavy drinking behavior after work or on liberty during deployment is a manifestation of cultural tradition. These military expressions and lifestyles operate in parallel with the availability of alcohol on the military bases, in nearby hotels, or off-base bars are well known risk

factors for alcohol consumption and its negative consequences (Ames and Cunradi, 2004:252-257).

In general, MVCs are perceived as a critical cause of injury in the military. In particular, the most likely causes of injuries include physical training, military parachuting, privately owned vehicle crashes, sports, falls, and military vehicle crashes. Historically, private MVCs which are the third highest cause of injury, have been the leading cause of mortality and morbidity among active duty military members (Canham-Chervac et al., 2010:11-18).

As far as the USAF is concerned, for the past two decades, FY 1988 to 2007, MVCs are one of the most persistent problems leading to injury and death. Markopoulos, in his study focused on both driver and passenger and revealed that in 2007, the private motor vehicle mishap rate was close to that in 1988. However, the fatality rate had been reduced from FY 2002 through 2006, rising again in 2007 to 12.77% (Markopoulos, 2009). Furthermore, males 17-24 years old and the rank of Airman are common characteristics for service members involved in MVCs. The most risky time of the day for MVCs was 1400-1759 hours, while fatal MVCs peaked between 2200-0559 hours. In addition, the use of seat belts was a significant factor with respect to injury, while alcohol consumption was not found to be statistically significant in those crashes. Considering rank, NCOs and Senior NCOs, tended to be under the influence of alcohol more than other ranks when they were driving in MVCs. Ultimately, MVCs cause significant economic burden to society because death and human loss or injury affect USAF productivity and is a perceived source of emotional cost to the victims and their families.

MVC Economic- Social Impact

Following the analysis of the potential factors that influence the consequence of traffic risk, it is prudent to point out the economic and social cost of MVCs.

According to the US DOT, the total economic cost of US MVCs for FY 2000 was \$230.6B (NHTSA, 2002). This is the aggregate cost of 41,821 fatalities, 5.3 million non fatal injuries and 28 million damaged vehicles. The analysis of this cost can be summarized as follows:

- (i) Lost market productivity \$61 billion
- (ii) Property damage nearly \$59 billion
- (iii) Medical expenses \$32.6 billion
- (iv) Travel delay \$25.6 billion
- (v) Life time cost \$977,000

In terms of taxes, public revenues paid for about 9% of all MVCs expenses, tax payer expense was \$21 billion, accounting for over \$200 in additional taxes per household. This analysis demonstrates that MVCs are a source of excessive financial burden for individual household budgets and the nation in general.

Obviously perhaps the most negative outcome of an MVC is the victim's death, in which a human loss that cannot be measured in terms of economic cost. In addition, people who suffer total or partial disabilities negatively and permanently impact their social roles for the rest of their lives. In addition, economic costs cannot reimburse the psychological impacts and depression resulting from MVCs injuries. The emotional cost on families and friends is beyond measure and sufficient compensation cannot be realized.

These negative economic and social consequences of MVCs show the far-reaching effects. Measuring the MVCs cost, on a comparison basis provides a vital instrument, to endorse the worthiness of any potential intervention program.

Summary

MVCs are a global public health problem with devastating economic and psychological outcomes for the victims and their families. In the military, they are the third leading cause of injury after physical training and parachuting. With that knowledge, DoD has experienced for many years the negative consequences on operations and productivity due to death and disability of service members. Efforts to determine what factors might influence the road traffic risk and crash severity, have been undertaken. However, causal factors are still hidden, areas that can be further investigated to provide valuable information about MVCs involving USAF personnel.

Being a US Air Force member is completely different from being a civilian. Military life can be stressful enough with changing assignments, deployments and high operations tempo. In this thesis, a different approach is conducted to reconcile the data and reveal perspectives for factors such as alcohol or time excluding others that might inflate the outcome of the research to explain potential factors that influence the severity of MVCs. Specifically, operations tempo is carefully analyzed as it characterizes military life and represents external factors as they impact the work environment. This is a major addition on the study of MVCs. Moreover, this thesis relies on constructing a new data base utilizing AFSC historical data for modeling the frequency of MVCs as another cost driver for the excessive financial burden on the DoD budget. Considering the negative outcome on AF productivity as well as the

devastating consequences on victims, this thesis will help identify target areas for USAF prevention programs.

III. Methodology

Research Approach

This chapter describes the process by which this thesis conducted this research. Specifically, the methodology was based on categorical and multiple regression analysis of the raw data collected by AFSC for the periods of FY 1988 to 2010. Explanations will be provided for the process by which these data were collected and compiled as well as for the exploratory data analysis and regression techniques employed.

This study incorporates AFSC data for private MVCs in which only US Air Force military personnel were involved as drivers. Passengers and pedestrians are excluded. For this reason, using the statistical tool JMP[®], categorical data analysis and analysis of variance (ANOVA) will be applied to detect dependencies and modeling parameters applicable to the research questions defined in Chapter I.

Given the DoD cost policy throughout these years, it is assumed that the cost of MVCs is a function of the following elements as they are both been identified as cost drivers of the total financial burden MVCs cause to the USAF budget:

1. Severity of an MVC
2. Frequency of MVCs

In particular, both the severity and frequency of MVCs are associated with days of hospitalization, work loss days, and many other negative consequences, increasing the relative cost accordingly. For that reason, factors that influence severity and frequency of MVCs need to be identified.

Information- AFSC Database

The analysis of this research was based on the database compiled from raw data provided by AFSC for FY 1988 through 2010. This thesis focuses on MVCs in which US Air Force military personnel were involved as drivers, in off-duty and off-base travel. Germane demographics such as gender, age, and rank are included.

Additionally, information about the date and time of the crash, type of vehicle, mishap class, and type of injury, seatbelt use, and toxicology (TOX) are also included. In cases of alcohol involvement, the relative level of Blood Alcohol Concentration (BAC) percentage is provided. This information is employed for the analysis that explores the severity of a crash. Furthermore, information and analysis for estimating the cost growth of total injury relative to MVC, as well as, trends and reports throughout this period will be also provided.

Testing Categorical Variables

First, the Chi-Square X^2 - test will be used to investigate several hypotheses about whether specific characteristics of selected categorical variables affect or are associated with the severity, and consequentially, the cost of MVC.

Contingency Analysis

Contingency analysis is a method that tests the potential relationship between two categorical variables. It is the appropriate method when there is one categorical response variable and one categorical predictor variable, in order to detect if there is dependency or association between them. In particular, the hypothesis to be tested is the association or dependence of population variables that share two different characteristics. Using SAS JMP[®], this analysis is initially represented by a Mosaic plot, Contingency Table and test report (SAS, 2011).

The Mosaic Plot is a graphical representation of the two-way frequency table. It is divided into rectangles, so that the area of each rectangle is proportional to the proportions of the Y variable in each level of the X variable (Hartigan and Kleiner, 1981; Friendly, 1994).

The Contingency Table is a two-way frequency table. There is a row for each factor level and a column for each response level. Contingency tables depict how many observations there are for a specific level of a particular combination of categorical variables, including how many times we observe this combination according to dependency.

The test report shows the results of two tests as they determine whether the response level rates are the same across X levels. This information is used to check the hypotheses:

- H0: Independent Variables (Null hypothesis)
- H1: Dependent Variables (Alternative hypothesis)

In particular, this study employs the Chi-square test at $\alpha=0.05$ level of significance, considering whether the following variables associated with the severity of a crash is represented by the variable injury class in the following levels:

- (i) Fatal
- (ii) Lost Time Case
- (iii) Lost time hours
- (iv) No lost time
- (v) Permanent partial disability

- (vi) Permanent total disability
- (vii) Treated and released

This thesis will focus on fatal permanent and partial disability accidents, as defined by DoD instructions (DoD, 2000).

The X variable represents every potential factor included in the AFSC data associated with the severity of a crash as described below:

1. Whether the following variables with their specific proportion that demonstrate demographic information such as gender, age and rank of USAF military personnel are related with the injury class of MVCs. The specific levels per variable are as follows:
 - a. Gender of the USAF military personnel:
 - (i) Male
 - (ii) Female
 - b. Age of USAF military personnel as it is demonstrated in the data base, represented by a dummy variable of collective population with common characteristics. This assists the identification process for the most influential part of the population given the broad range of their age.
 - (i) 17 - 20
 - (ii) 21 - 25
 - (iii) 26 - 30
 - (v) 31 – 35
 - (vi) 36 - 40
 - (vii) 41 - and older
 - c. Rank of the USAF military personnel incorporated in the data set, represented by a dummy variable for integration into the entire analysis. For analysis purposes, Brigadier General is included in the Field Grade group.

Similarly, Cadets are included in the Company Grade group. The following are the rank groups:

- (i) Airman: Airman Basic, Airman, Airman First Class, and Senior Airman
- (ii) Company Grade: Cadet, Second Lieutenant, First Lieutenant, Captain
- (iii) NCO: Staff Sergeant, Technical Sergeant
- (iv) Senior NCO: Master Sergeant, Senior Master Sergeant, Chief Master Sergeant
- (v) Field Grade: Major, Lieutenant Colonel, Colonel, Brigadier General

2. Whether the Time of Day is related with the severity of a crash represented by a Dummy variable in the following levels:

- (i) 0100-0400
- (ii) 0500-0800
- (iii) 1500-1800
- (iii) 0900-1400 & 1900-2400

3. Whether the type of vehicle is associated with the injury class:

- (i) Motorized four-wheeled
- (ii) Motorized two-wheeled

4. Whether the use of seatbelt is related with the injury class:

- (i) Seatbelt usage
- (ii) Non-seatbelt usage

5. Whether alcohol involvement affects the injury class:

- (i) Alcohol involvement
- (ii) No alcohol involvement

6. Whether gender of military personnel is related with alcohol involvement in

a MVC:

- (i) Male
- (ii) Female

7. Whether the rank of military personnel is related with alcohol in a MVC.

8. Whether FY during the following timeframes (escalation with respect to operations tempo), is related with the injury class:

- (i) FY 1988, 1992-1994, 1997-2000 peace time
- (ii) FY 1989-1991 US Invasion of Panama, Persian Gulf War
- (iii) FY 1995-1996 United States as part of NATO-acting peacekeepers in former Yugoslavia
- (iv) FY 2001-2004 United States and Coalition Forces vs. the Taliban regime in Afghanistan to fight terrorism
- (v) FY 2005-2009 United States and Coalition Forces vs. Iraq

This part of the analysis is of a great importance, as this thesis conducts categorical data analysis to investigate whether operations tempo, in terms of FY, is correlated with the injury class. The research considering the facts that:

- (i) MVCs are not uniformly distributed between FY (1988-2009)

assuming that periods of time demonstrate high or low frequency of MVCs.

(ii) Specific years of the given time range (FY 1988 to 2009) characterized high or low operations tempo, according to the war timelines for the USAF.

This thesis is based on the literature related to American historical war timelines as represented below, in Table 2, to construct dummy variable for incorporating the concept of operations tempo into the study.

Table 2. American War Timelines, courtesy of, *The New York Public Library Desk Reference, 3rd Edition, 2011* (about.com American History, 2011)

1989	US Invasion of Panama	United States vs. Panama
1990-1991	Persian Gulf War	United States and Coalition Forces vs. Iraq
1995-1996	Intervention in Bosnia and Herzegovina	United States as part of NATO acting as peacekeepers in former Yugoslavia
2001	Invasion of Afghanistan	United States and Coalition Forces vs. the Taliban regime in Afghanistan to fight terrorism.
2003	Invasion of Iraq	United States and Coalition Forces vs. Iraq

Second, this issue will be integrated into this study through another approach with the following FY groups. These FY groups have common characteristics relative to peace or war in order to incorporate the concept of operations tempo. This calculation of the dummy variable utilizes the following code scheme to assist the analysis of this thesis in answering the following research questions:

(9) Whether FY with the following levels (operations tempo war/peace) associated with the injury class.

(i) FY 1988, 1997-2000: peacetime

(ii) FY 1989-1996 & FY 2001-2009: war

- (10) Whether Rank and alcohol involvement is associated with FY
(operations tempo) given a MVC occur.

Furthermore, this study will use the method for multiple comparisons of means (Tukey-Kramer) in order to interpret at a 95% confidence interval the most important proportion of categorical variables as listed above with respect to the severity of a crash. The Tukey-Kramer method is a single-step multiple comparison procedure and statistical test generally used in conjunction with ANOVA to find which means are significantly different from another. This method will help to identify which proportions are statistically equivalent, and recommend groups of the population with common characteristics.

Dummy Variables

In regression analysis, the independent variable that takes the values of 0 or 1 indicates the absence or presence of some categorical effect that may cause the outcome to change. This structure is commonly defined as a ‘dummy variable’, and it provides a valuable tool for applying multiple regression analysis involving categorical variables (Newbold et al., 2010). Such a variable gives opportunity for this study to examine different levels of a categorical variable by creating groupings using a code scheme. For example:

- 1: The population has a specific characteristic
- 0: The population doesn't have the specific characteristic

Considering the fact that the amount of the dummy variables should be equal with the number of the relative levels minus 1 ($n-1$), the goal is to reduce the levels of each categorical variable ($\# \text{ Dummy Variables} = \# \text{ groups} - 1$).

Discretization

In cases of mix distribution (continue variable and point mass), it is imperative to transform the continuous variable to nominal or discrete form. This method is suitable when there is a continuous response and we have to make it discrete (categorical).

Analysis of Variance (ANOVA)

The variety of categorical variables and the different levels contained in the AFSC data is the incentive for this thesis to detect the means of those variables. In statistics, ANOVA is a collection of statistical models and procedures, in which the observed variance is partitioned into components due to different explanatory procedures. It provides a statistical test of whether the means of several groups are all equal (Newbold et al., 2010).

Considering that every model has inputs and output, it is imperative to build a parsimonious model that inherently measures to the simplest plausible model with the fewest possible number of variables.

In particular, this study uses the test statistic, F which is the ratio of two different elements: $F = \text{chi-square distribution (in between variability)} / \text{chi-square distribution (within variability)}$, in order to test the status quo or to approve a personal opinion. The F test is designed to ensure that the model uses specific proportions of variables that can explain variability. The interpretation determines the similarity of characteristics of the population. If variability is demonstrated, the F test results in values so large, that by comparison, the p-value is small so as to reject the null hypothesis.

The p-value or calculated probability is the probability of rejecting the null hypothesis (H_0) of a study question when that hypothesis is true. It is usually a

hypothesis of no difference or equal while, the alternative (H_1) is the opposite and the source of investigation. The term significance level (α) is used to refer to a pre-chosen probability, so that when P value is less than (α) then the null hypothesis is rejected.

The scope of this study is to apply the F-test at $\alpha = 0.05$ level of significance, in order to consider whether the predictor variables impact the response variable:

Response Variable

As stated in Chapter I, this research seeks to identify predictors of the number of MVCs, or in other words, what affects the frequency of MVCs and, as a consequence, the cost to the USAF. In that case the response variable is the amount of the MVC, the measurable variable of interest is also known as dependent variable.

Predictor Variables

Several possible predictor variables are included in the USAF row data. The effort of this thesis is to construct a data base with the variables that influence the frequency of MVCs, irrelevant of the level of their predictive ability. These variables are also known as independent variables and are divided in two categories:

- (i) Quantitative Variables as measured on a numerical scale
- (ii) Qualitative Variables that are not measured on a numerical scale.

This study identifies many independent Variables that influence the frequency of MVCs, and the majority of which are associated with human and environmental factors. In particular, the predictor variables this thesis extracted from the USAF raw data fall into the following broad categories and respective subcategories:

The predictor variables are as follow:

- a. Gender of USAF military personnel with two levels:
 - (i) Male
 - (ii) Female
- b. Age of USAF military personnel with six levels:
 - (i) 17 - 20
 - (ii) 21 - 25
 - (iii) 26 - 30
 - (v) 31 - 35
 - (iii) 36 – 40
 - (iv) 41 and older
- c. Rank USAF military personnel separately in order for this study to detect the specific rank, considering the rule of 10:1 that is the most influential to the frequency of MVCs:
 - (i) Airman Basic
 - (ii) Airman
 - (iii) Airman First Class
 - (iv) Senior Airman
 - (v) Staff Sergeant
 - (vi) Technical Sergeant
 - (viii) Master Sergeant
 - (ix) Senior Master Sergeant
 - (x) Chief Master Sergeant

- (xi) Cadet
- (xii) Second Lieutenant
- (xiii) First Lieutenant
- (xiv) Captain
- (xv) Major
- (xvi) Lieutenant Colonel
- (xvii) Colonel
- (xviii) Brigadier General

d. Time of day with the following levels:

- (i) 0100-0400
- (ii) 0500-0800
- (ii) 1500-1800
- (iii) 0900-1400&1900-2400

e. Type of vehicle:

- (i) Motorized four-wheeled
- (ii) Motorized two-wheeled

f. Seatbelt with two following levels:

- (i) Seatbelt Usage
- (ii) Non Seatbelt Usage

g. Alcohol involvement

(i) Yes

(ii) No

h. Fiscal Year from FY1988 to 2009 in 21 levels, by which this thesis incorporates operations tempo in the analysis. It is pointed out that every year is represented by the numbers 1 to 21 accordingly. This policy is suitable for nominal variables to avoid the danger of overinflating the coefficient of determination.

Multiple Regression Analysis

Regression analysis provides a tool for analyzing possible predictive relationships when the response is nominal or ordinal. Multiple regression analysis is a method for modeling the linear relationship between a continuous variable and one or more independent variables. This thesis seeks to develop a model that predicts the frequency of MVCs as a crucial element that affects the total cost burden to the USAF and society in general.

In this effort, JMP[®] software will be employed to accomplish the analysis in order to identify the best model for estimating the frequency of MVCs. The problem of MVCs cost burden is approached by detecting data sources that affect the frequency of MVCs. Since the foundation of this effort is based on statistical test and linear regression modeling, the analysis approach collects as much data as possible, retaining only the significant variables with the result to satisfy the necessary assumptions.

The standard least squares method will be used to derive a model that estimates the form of the functional relationship between the predictors and response variable that minimize the sum of squared deviations from the predicted values at each level of the predictors. This means the model is fit such that, the sum of squares

of differences of observed and predicted values is minimized (Newbold et al., 2010:12-15).

Considering the large amount of candidate predictor variables, the research will repeat the process in order to achieve the desired results. It is pointed out that the research will continue adding variables to the model until the number of variables equals about one-tenth of the number of data points used in the model. This method ensures that the final model will not be over-fitted.

In regression analysis, the independent variables do not mean they are always independent. Many times correlation exists between them that cause negative effects known as multicollinearity. In fact, the variance of the regression coefficients can be inflated so much that they look like they are not statistically significant.

The Variance Inflation Factor (VIF) is a statistical tool this thesis will use to detect the existence of multicollinearity among the independent variables. Threshold of five (5) is a critical value for the VIF, and any score more than five indicates negative effects of multicollinearity (Newbolt et al, 2010).

Furthermore, data points that over influence the model is another problem this study might phase during the regression analysis. Cook's Distance is a valuable statistical tool that detects potential influential data or outliers with the value of 0.25 as a critical threshold.

Data rarely behave well enough to fit perfectly, leaving an amount of error which is known as residuals or error. It is the difference between the observed and predicted values that measures the closeness of fit of the predicted values to the actual values. The error term is unknown because the true model is unknown. In addition, as long as the model adequately explains the data then the following assumptions will be satisfied:

- (i) Normality
- (ii) Constant variance
- (iii) Independency

This means that the residuals demonstrate pure noise and do not show any pattern so as to assume there are missing data. Furthermore, they are normally distributed around the residual mean and have constant variance. Analysis of residuals consists of the following graphs and statistics of the regression analysis in order to determine that model assumptions are satisfied.

- (i) Histogram of residuals to assess normality as well as the comparison of both residuals and studentized residuals.
- (ii) Shapiro Wilk test is used and high p-values are the power of the test to accept the null hypothesis of normality.
- (iii) Residual by predicted plot is the visual technique for detecting constant variance.
- (iv) Breusch Pagan test to assess constant variance.

The explanatory power of the regression is represented by the R^2 value, also known as the coefficient of determination, and often described as the proportion of variance explained by the model. It is pointed out that R^2 does not imply causation. It takes values between 0 and 1. Specifically, if the regression is ideal, all the residuals are zero and R^2 is 1, otherwise it takes values according to the ability to explain the relative variability. This thesis will use the adjusted R^2 as more accurate technique of measurement when adding additional predictors into the model.

Ultimately, model validation will not be applied using the jackknife technique due to the difficulty of using subsets of observations to detect weakness as a result of data scarcity.

IV. Analysis and Results

Chapter Overview

It is important to understand that historical data are the most valuable sources for analysis as it synthesizes the foundation for the research. This study provides general information on MVC trends, along with the estimation of the total injury cost in 2010 CY dollars. The analysis is divided in two parts:

1. The outcome of the research is demonstrated through contingency tables in order to deal with the identification of every variable that is related to the severity of MVCs, and as a consequence, total AF cost. In addition, identification of factors, associated with alcohol consumption, time, and environmental conditions (FY) that characterize the military life and affect the severity or frequency of MVCs.
2. The outcome of the research through analysis of variance to deal with the identification of variables related to the volume of MVCs and, as a consequence, the total injury cost to the USAF. The process is based on multiple regression analysis by using the least squares method.

Raw Data

By studying the raw data it has been found that there is information irrelevant to the research that should be excluded:

1. Non-active duty AF personnel such as Army, Navy, and Civil Service.
2. Pedestrians and other activities beyond operation of a motor vehicle.
3. On Base/On Duty activities.
4. Data related to FY 1997 and FY 2010, since the entire fiscal year's information is not provided.

5. Additionally, this study detected duplicates, which are also excluded.

It considers, as missing data and not information, inconsistencies such as the following values:

1. Age equals to “0”
2. Time equals to “0”

As far as alcohol is concerned, this study employs the variable “alcohol involvement” and not the (BAC) due to reporting inconsistencies and many missing data. This approach provides a better representation of alcohol and increases the potential of the analysis to capture the influence of alcohol on MVCs.

As mentioned earlier, this research focuses on the MVC data from AFSC for FY 1988 through FY 2009 and for MVCs in which USAF personnel have been involved as drivers. Based on the AFSC data, Figure 15, provides a graphical representation of the USAF PMV accidents from FY 1988 through FY 2009.

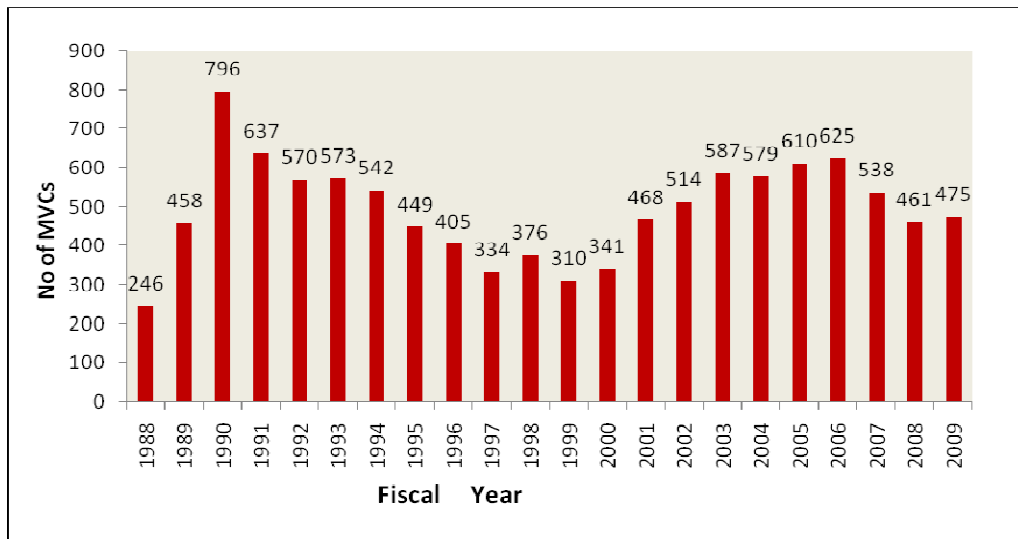


Figure 15. USAF PMV Accidents, FY 1988-2009

It is revealed that MVCs involving USAF personnel do not follow similar trends with that of society at large or is representative of the total USAF demographic. Recall that in Chapter II, it was noted that US MVCs have steadily declined over the past two decades, most likely due to legislation and safety laws. As shown in Figure 15, the number of USAF MVCs increased from FY 1988 to FY 1990, trended downward until FY 1999, until increasing again from FY 2001 to FY 2006.

It is worth pointing out that FY 1988 showed the lowest level of MVCs. In that year 246 MVCs occurred while, from that period, there are fluctuations without any indication of steady decreasing attitude. In fact in 2009, MVCs increased to 475.

Furthermore, fatal, partial or total disability rates follow similar trends as revealed in Figure 16. Specifically, fatalities and severe MVCs appear to peak at their highest level between FY 1988 and FY 1992 and FY 2001 to FY2004 while a high fatality rate is indicated for the period FY1994 to FY 1996.

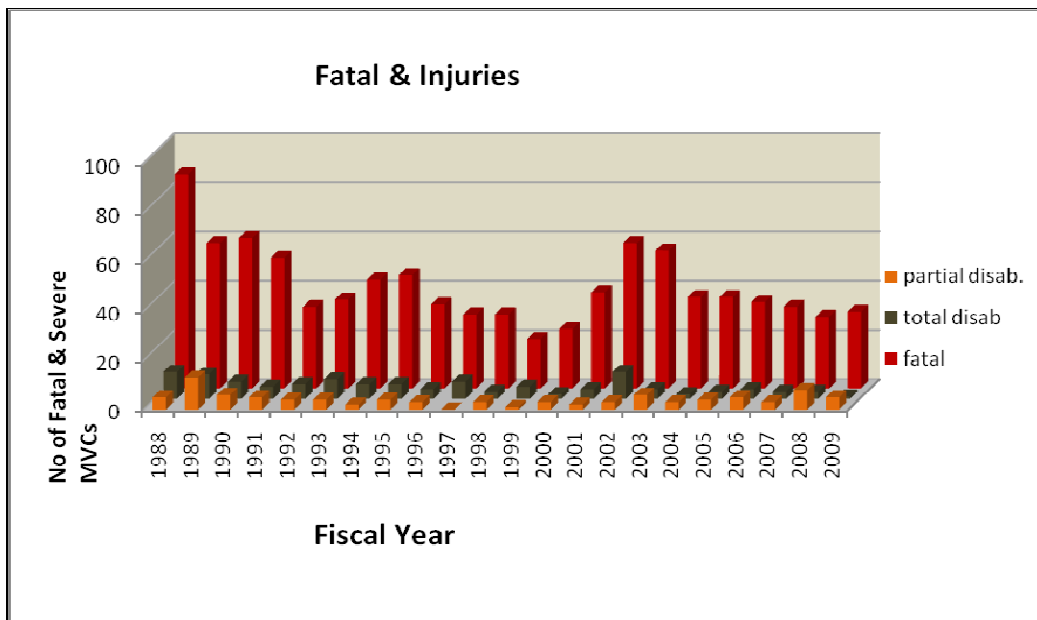


Figure 16. Fatal and Severe Injuries of USAF PMV Accidents FY 1988-2009

As depicted in Figure 17, the majority of MVCs are not alcohol related, however alcohol involvement was higher in FY 1990-FY1991 and demonstrated a downward trend until 1999, only to increase again until FY 2007, with the highest levels during FY 2001- FY2004.

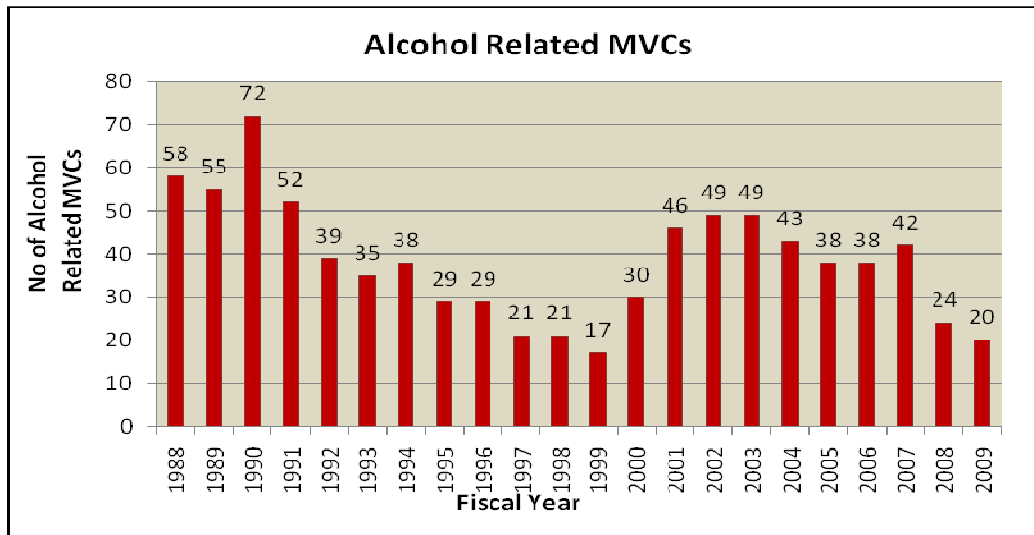


Figure 17. Alcohol Involvement in USAF-PMV Accidents FY 1988-2009

Based on AFSC data, rank group Airman and NCO were involved in the majority of the accidents, while almost all of them with some exceptions displayed the same tendency of being involved in MVCs according to FY. Figure 18 presents the association of rank groups and MVCs during FY 1988 to FY 2009. Specifically, rank groups Airman and NCO display the highest involvement.

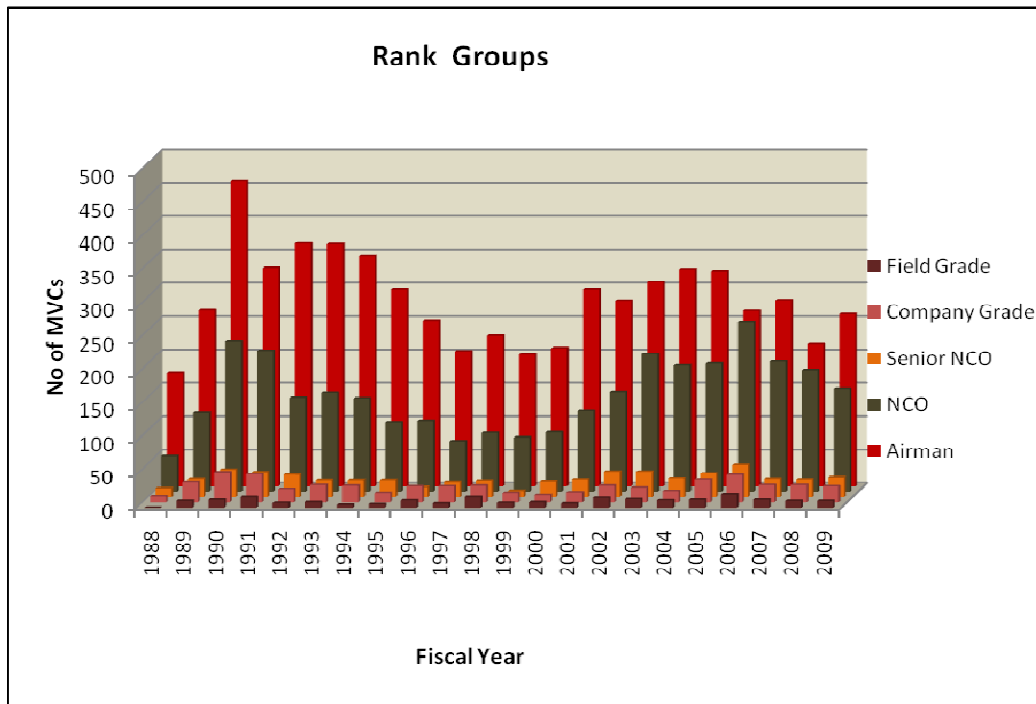


Figure 18. USAF Rank Groups in PMV Accidents FY 1988-2009
Total Injury Cost

Finally, during this period USAF personnel were involved in 10,814 MVCs, costing to the USAF \$ 356M. The estimation, based on 2010 CY dollars, utilized the relative USAF Weighted inflation Indices, as based on OSD Raw Inflation Rates (appropriation 3400, O&M) Base Year (FY) 2010. Table 3 depicts the cost per every year, FY 1988 to FY 2009. Note that the cost is at the lowest levels in FY 2000 and FY 2009 and the most excessive costs FY 1989-1990 and FY 2002.

Table 3. PMV Accidents - Total Injury Cost FY 1988-2009

Fiscal Year	Injury Cost	Weighted Index	Total Inj cost (CY 2010 \$)
1988	13,054,326	0.641	20,365,563.18
1989	23,629,645	0.667	35,426,754.12
1990	21,179,689	0.669	31,658,727.95
1991	16,772,322	0.721	23,262,582.52
1992	11,843,959	0.741	15,983,750.34
1993	10,376,852	0.753	13,780,679.95
1994	12,243,026	0.771	15,879,411.15
1995	12,474,907	0.785	15,891,601.27
1996	8,529,297	0.800	10,661,621.25
1997	9,637,075	0.810	11,897,623.46
1998	8,636,239	0.816	10,583,626.23
1999	11,326,248	0.824	13,745,446.60
2000	7,291,557	0.836	8,721,958.13
2001	10,361,103	0.848	12,218,281.84
2002	21,582,571	0.857	25,183,863.48
2003	17,111,873	0.869	19,691,453.39
2004	13,870,735	0.890	15,585,095.51
2005	12,423,592	0.922	13,474,611.71
2006	10,593,137	0.945	11,209,668.78
2007	11,810,945	0.969	12,188,797.73
2008	10,063,890	0.987	10,196,443.77
2009	8,879,703	0.999	8,888,591.59
Total	283,692,691		356,496,153.97

The cost displayed graphically in Figure 19, indicate FY 1989-FY 1991 and FY 2001- FY 2005 as the most costly periods.

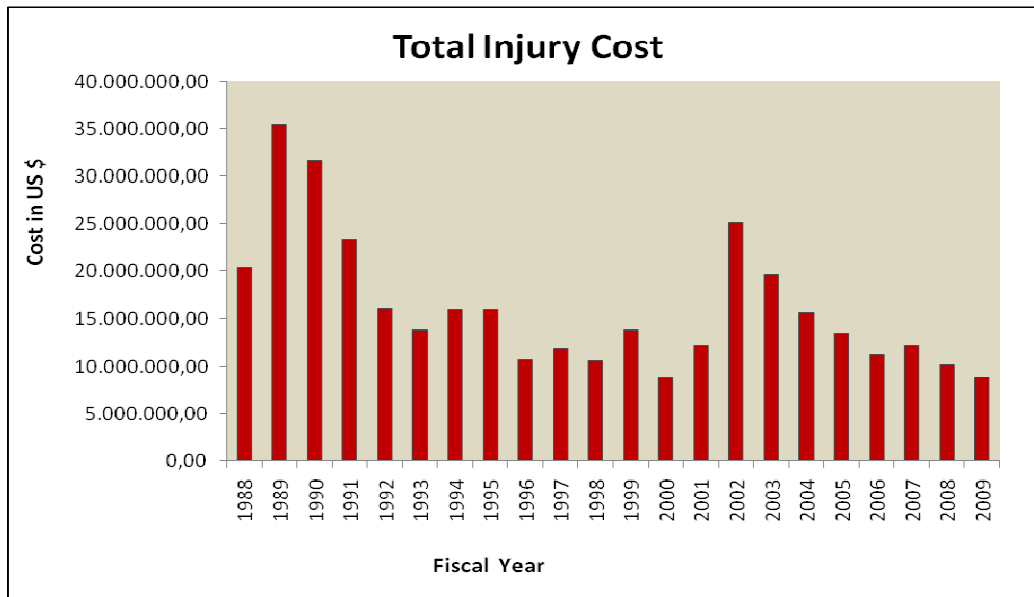


Figure 19. Total Injury Cost of USAF PMV Accidents, FY 1988-2009

Consistent with the order of policy objectives, this study will continue a step by step analysis of questions presented in Chapters I and III related to the categorical data analysis and regression analysis.

Research Questions

Categorical Data Analysis

This thesis carry out categorical data analysis using Mosaic plots and contingency tables and reports to investigate the association and the influence of every categorical variable on the severity of a crash which is represented by the term injury class.

1st Objective

As stated in Chapter I, the first policy objective of this study identifies factors associated with and influencing the injury class. For that reason, a series of investigative steps will take place, based on AFSC data, considering the severity of a MVC will be detected by one variable at a time. In particular, FIT Y by X is the

command this study uses for every categorical variable to test the hypothesis of dependency.

Injury class (Y response) for the following categories:

- (i) Fatal
- (ii) Lost Time Case
- (iii) Lost time hours
- (iv) No lost time
- (v) Permanent partial disability
- (vi) Permanent total disability
- (vii) Treated and released

The X variable represents every potential factor included in the AFSC data and associated with the injury class below:

1. Whether the factors of demographics such as Gender, Age and Rank of US AF military personnel are associated with the injury class of MVCs.

Contingency Analysis of Injury Class by Gender

The Mosaic Plot demonstrates whether gender of USAF military personnel is associated with injury class. In particular, Figure 20 indicates that colors and tables in the plot are not uniformly distributed, suggesting a pattern due to dependency.



Figure 20. Mosaic Plot Injury Class by Gender

In addition, Pearson Chi-square $p\text{-value} < 0.0001$, is a strong indication to reject the null hypothesis and support the fact that age and injury class are related. The following contingency table confirms the evidence of association and will be described in detail in the following paragraphs.

Table 4. Contingency Table Injury Class by Gender

Count Total % Col % Row %	Fatal	First Aid Case	Lost Time Case	Lost Time Hours	No Lost Time	Permane nt Partial Disability	Perman ent Total Disabili ty	Treated and Release d	
Female	85 0.79 9.31 4.32	1 0.01 7.69 0.05	1826 17.04 19.52 92.83	0 0.00 0.00 0.00	27 0.25 18.37 1.37	8 0.07 8.70 0.41	8 0.07 6.96 0.41	12 0.11 15.00 0.61	1967 18.36
Male	828 7.73 90.69 9.47	12 0.11 92.31 0.14	7528 70.26 80.48 86.05	1 0.01 100.00 0.01	120 1.12 81.63 1.37	84 0.78 91.30 0.96	107 1.00 93.04 1.22	68 0.63 85.00 0.78	8748 81.64
	913 8.52	13 0.12	9354 87.30	1 0.01	147 1.37	92 0.86	115 1.07	80 0.75	10715

From FY 1988 to FY 2009, USAF military personnel were involved in 10,894 private MVCs as drivers. For 10,715 provided gender information as shown in Table 4.

1. 1,967 were female drivers.

(i) 85 females lost their lives in fatal MVCs, accounting for 9.31% of all fatal MVCs. The likelihood for a female to die in fatal accident was 4.32%.

(ii) 27 females were involved in no lost time case accidents, while they experienced 0.41% risk of permanent total or partial disability due to a severe MVC. 12 females were involved in MVCs were treated and released which representing 15% of the total relative type of accidents.

2 8,748 MVCs were male drivers for the same period.

(i) 828 male drivers lost their lives in fatal MVCs representing 90.69% of all fatal accidents. This proportion is 81.38% higher than that of females and is logical since the majority of USAF personnel is males. Additionally, males raised the risk of dying in a fatal accident by 9.47%, 5.15% higher than that of females. The evidence reveals that male gender and fatal MVCs are significantly related.

(ii) In addition, 84 and 107 males had been involved in permanent and partial disability accidents, or 91.30% and 93.04% of the respective categories. Beyond that, the risk that males suffered permanent partial or total disability was 0.96% and 1.22% accordingly, again higher than that of females. These rates illustrate the strong association of male gender and severity of MVCs.

In conclusion, males are more vulnerable than females in every type of MVC, while they present the highest risk involvement in a fatal or severe accident with negative consequences to their lives. In fact, the rate of involvement and the relative risk are extremely disproportionally distributed according to gender demonstrating that gender and severity of a crash are statistically associated. Figure 21, depicts the analysis results.

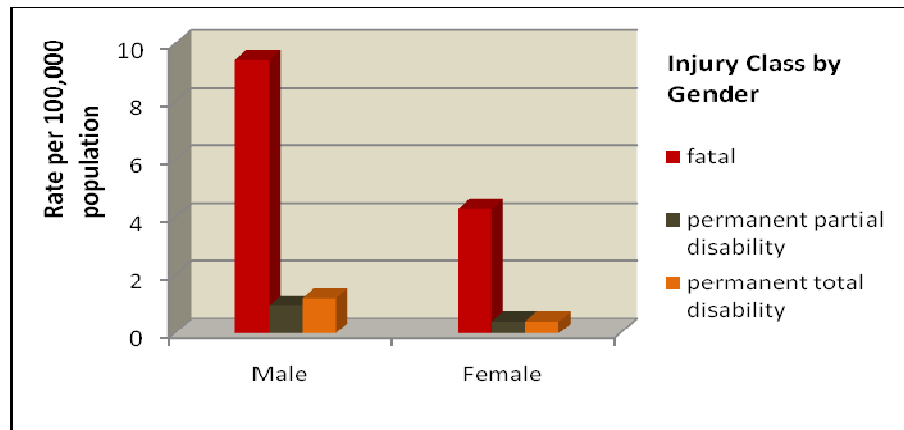


Figure 21. Percentage of Fatal and Severe USAF PMV Accidents by Gender per 100,000 Military Personnel

Contingency Analysis of Injury Class by Age Groups

Given the fact that the population demonstrates a broad age range, it is vital to identify population segments that display common characteristics. As a result, individuals should be included in groups according to their age. The histogram of the age distribution involved in MVCs in Figure 22 highlights the skew of the data and provides information for the cut points of the relative dummy variable. Ages ranging from 17-60 years are depicted below and have outliers.

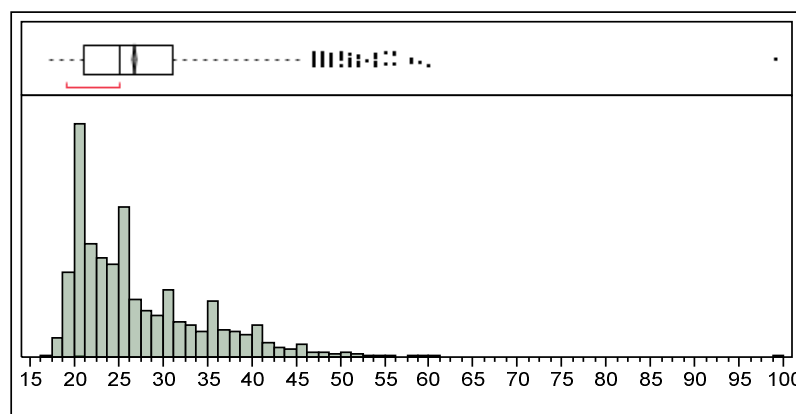


Figure 22. Age Distribution of USAF PMV Accidents FY 1988-2009

As a consequence, it is visually observable that age is not uniformly distributed. Table 5 below depicts the maximum, median, and minimum values.

Table 5: Age Quantiles

100.0%	maximum	99.000
99.5%		49.000
97.5%		43.000
90.0%		37.000
75.0%	quartile	31.000
50.0%	median	25.000
25.0%	quartile	21.000
10.0%		20.000
2.5%		19.000
0.5%		18.000
0.0%	minimum	17.000

Based on the statistical analysis of the AFSC data, relative literature and common logic, this research integrates the age groups into the contingency analysis with a dummy variable in the following code scheme.

- 1: 17 – 20
- 2: 21 – 25
- 3: 26 – 30
- 4: 31 – 35
- 5: 36 – 40
- 6: 41 and older

According to the Mosaic Plot, Figure 23, there is a trend and, as a consequence dependency considering the plot does not display uniform distribution.

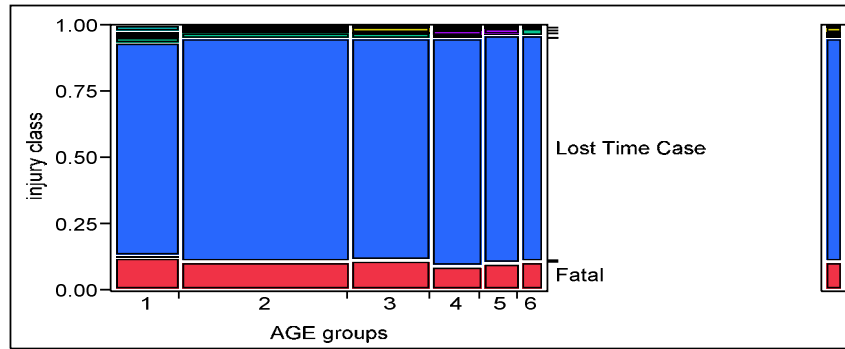


Figure 23. Mosaic Plot Injury Class by Age

In addition, considering the Pearson, $p\text{-value} < 0.0001$, this research rejects the null hypothesis, assessing that injury class as it represents the severity of a crash and age, are statistically dependent. Moreover, the following contingency table provides additional information related to that evidence.

Table 6. Contingency Table Injury Class by Age

Count Total % Col % Row %	Fatal	First Aid Case	Lost Time Case	Lost Time Hours	No Lost Time	Permanen t Partial Disability	Permanen Total Disability	Treated and Release d	Total
1 (17-20)	168 2.00 18.42 12.62	4 0.05 30.77 0.30	1072 12.73 15.12 80.54	1 0.01 100.00 0.08	20 0.24 16.26 1.50	15 0.18 16.30 1.13	16 0.19 13.91 1.20	35 0.42 45.45 2.63	1331
2 (21-25)	349 4.14 38.27 10.57	6 0.07 46.15 0.18	2794 33.18 39.42 84.62	0 0.00 0.00 0.00	51 0.61 41.46 1.54	35 0.42 38.04 1.06	47 0.56 40.87 1.42	20 0.24 25.97 0.61	3302
3 (26-30)	180 2.14 19.74 11.17	2 0.02 15.38 0.12	1354 16.08 19.10 84.00	0 0.00 0.00 0.00	23 0.27 18.70 1.43	15 0.18 16.30 0.93	25 0.30 21.74 1.55	13 0.15 16.88 0.81	1612
4 (31-35)	91 1.08 9.98 9.24	0 0.00 0.00 0.00	845 10.03 11.92 85.79	0 0.00 0.00 0.00	15 0.18 12.20 1.52	14 0.17 15.22 1.42	14 0.17 12.17 1.42	6 0.07 7.79 0.61	985
5 (36-40)	75 0.89 8.22 10.03	1 0.01 7.69 0.13	645 7.66 9.10 86.23	0 0.00 0.00 0.00	5 0.06 4.07 0.67	10 0.12 10.87 1.34	10 0.12 8.70 1.34	2 0.02 2.60 0.27	748
6 (41+)	49 0.58 5.37 11.06	0 0.00 0.00 0.00	378 4.49 5.33 85.33	0 0.00 0.00 0.00	9 0.11 7.32 2.03	3 0.04 3.26 0.68	3 0.04 2.61 0.68	1 0.01 1.30 0.23	443
	912 10.83	13 0.15	7088 84.17	1 0.01	123 1.46	92 1.09	115 1.37	77 0.91	8421

(i) Of particular note, for the entire population involved in MVCs, there is age information for 8,421 drivers. The group that displays the greatest amount of accidents is 21-25 years old, accounting for 3,302 MVCs or 38.27% of all fatal accidents for that period. However, this age group represents the third highest risk for a fatal MVC involvement considering the 10.57% result for that particular demographic. So by extension, drivers for that age range demonstrate a very high risk rate of permanent partial or total disability. Specifically 35 and 47 people remained permanent partial, and totally disabled, respectively, accounting for 38.04% and 40.87% of all this type of accidents, with the relative risk rate as 1.06% and 1.42% accordingly.

(ii) The age group with the second highest involvement in fatal MVCs is 26-30 years old. Specifically, 180 drivers died between FY 1988 and FY 2009 accounting for 19.74% of all fatal MVCs. The likelihood of an individual in that age group being involved in a fatality is 11.17%, the second highest in the risk range but representing the greatest risk of 1.55% to suffer permanent total disability.

(iii) The population with the third highest involvement, 18.42% in fatal MVCs is the 17-20 age group. Presenting the greatest fatality risk (12.62%), this group was involved in 168 fatal crashes and also experienced a risk of 1.13% and 1.20% to remain permanently or totally disabled.

(iv) Individuals from age groups 31-35 and 36-40 years old were involved in 985 and 748 respective MVCs. Accordingly, their proportions in a fatal MVC are the lowest at 9.98% and 8.22%. On the contrary, group 36-40 experienced higher risk to be involved in fatal MVCs than 31-35 years old.

The evidence of association between age and injury class in MVCs, in Figure 24 below, indicates drivers between the ages of 21-25 had been engaged in the majority of the most severe accidents.

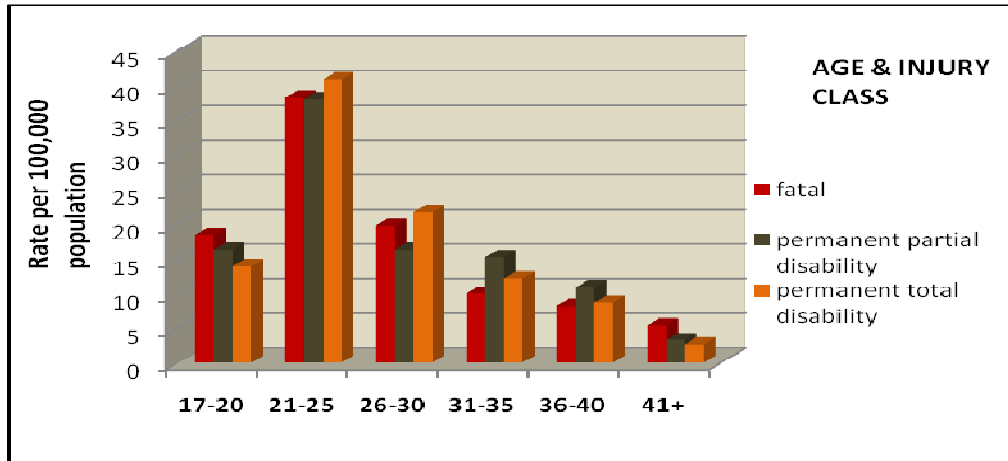


Figure 24. Fatality and Severe Injury Rates of USAF PMV Accidents per 100,000 Military Personnel by Age, FY 1988-2009

Every age group shares risk to die or to suffer permanent partial or total disability MVCs, regardless of their level of involvement in MVCs or their proportional representation in the USAF. This risk discrepancy depicted in Figure 25, shows drivers aged 17-20 at a high risk of fatality in a MVC, followed by the 26-30 and 40+ age groups. In addition, drivers aged 26-30 and 31-35 suffer higher permanent total disability risk, whereas those aged 31-35 and 36-40, permanent partial disability risk is at the highest levels.

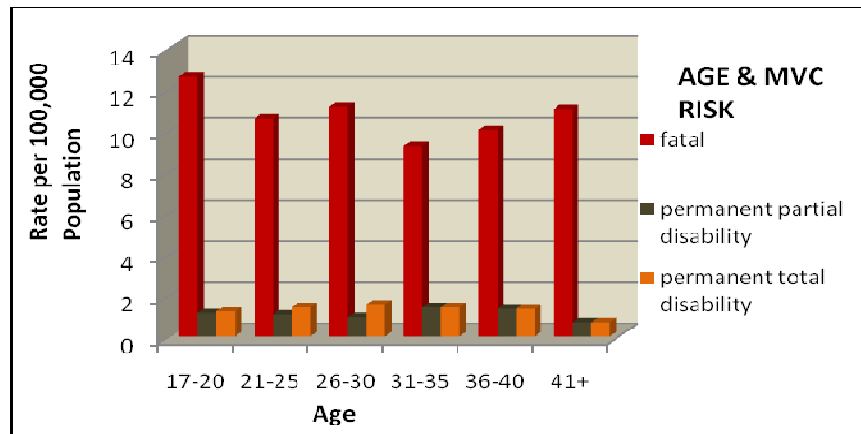


Figure 25. Percentage of Fatal and Severe USAF PMV Accidents by Age per 100,000 Military Personnel FY 1988-2009

Contingency Analysis of Injury Class by Rank

As far as the rank of USAF military personnel is concerned, this study is conducted as previously considering the broad range of ranks requires groupings and formation of a dummy variable in order to be integrated in to the research.

- (i) Group 1: Airman- (Airman Basic, Airman, Airman First Class, Senior Airman)
- (ii) Group 2: Company Grade- (Cadet, Second Lieutenant, First Lieutenant, and Captain)
- (iii) Group 3: NCO- (Staff Sergeant, Technical Sergeant)
- (iv) Group 4: Senior NCO- (Master Sergeant, Senior Master Sergeant, Chief Master Sergeant)
- (v) Group 5: Field Grade - (Major, Lieutenant Colonel, Colonel, and Brigadier General)

Figure 26 below suggests the dependency between injury class and rank groups, as not uniformly distributed. The investigative process of the hypothesis test, $p\text{-value} = 0.0131$ confirms this evidence so as to reject the null hypothesis and conclude that injury class and rank are statistically dependent.

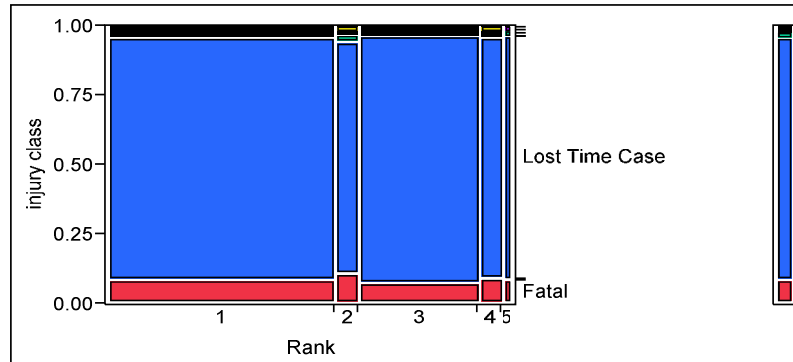


Figure 26. Mosaic Plot Injury Class by Rank

The following table provides in detail more useful information with respect to this association.

Table 7. Contingency Table Injury Class by Rank

Count Total % Col % Row %	Fatal	First Aid Case	Lost Time Case	Lost Time Hours	No Lost Time	Permanent Partial Disability	Permanent Total Disability	Treated and Released	
Airman	527 4.92 57.72 8.69	11 0.10 84.62 0.18	5278 49.26 56.43 87.08	1 0.01 100.00 0.02	75 0.70 51.02 1.24	44 0.41 47.83 0.73	67 0.63 58.26 1.11	58 0.54 72.50 0.96	6061 56.57
Company Grade	67 0.63 7.34 10.70	0 0.00 0.00 0.00	522 4.87 5.58 83.39	0 0.00 0.00 0.00	18 0.17 12.24 2.88	8 0.07 8.70 1.28	9 0.08 7.83 1.44	2 0.02 2.50 0.32	626 5.84
NCO	244 2.28 26.73 7.63	1 0.01 7.69 0.03	2831 26.42 30.27 88.55	0 0.00 0.00 0.00	45 0.42 30.61 1.41	30 0.28 32.61 0.94	28 0.26 24.35 0.88	18 0.17 22.50 0.56	3197 29.84
Senior NCO	56 0.52 6.13 9.14	1 0.01 7.69 0.16	532 4.97 5.69 86.79	0 0.00 0.00 0.00	5 0.05 3.40 0.82	7 0.07 7.61 1.14	10 0.09 8.70 1.63	2 0.02 2.50 0.33	613 5.72
Field Grade	19 0.18 2.08 8.72	0 0.00 0.00 0.00	191 1.78 2.04 87.61	0 0.00 0.00 0.00	4 0.04 2.72 1.83	3 0.03 3.26 1.38	1 0.01 0.87 0.46	0 0.00 0.00 0.00	218 2.03
	913 8.52	13 0.12	9354 87.30	1 0.01	147 1.37	92 0.86	115 1.07	80 0.75	10715

There were 10,715 MVCs from FY 1988 to FY 2009 in which USAF military personnel as drivers were identified by rank. More than half, 6,061 MVCs involving the Airman group, expressed the following characteristics with respect to the frequency and severity of a crash. Again, the risk level in which every rank group was placed was neither related to their involvement in MVCs nor to their proportional size in the AF. As stated in Chapter II, the number of service members in the AF is not identical among ranks. In particular:

1. Group 1: Airman- (Airman Basic, Airman, Airman First Class, and Senior Airman): In total 6,061 MVCs, of which 527 was fatal accounting for 57.72% of all fatal MVCs for that period. Whereas, their proportion of total fatal MVCs is the highest, the likelihood of an Airman driver to lose his life in a fatal crash is 8.69%, the third highest compared to other ranks. In addition, 44 and 67 drivers suffered permanent partial or total disability accounting for 47.83% and 58.26% of the analogous types of accidents. However, the relative risk of these ranks is the lowest at 0.73% and 1.11% accordingly. The lost time case accidents of this group, involving 5,278 individuals, accounts for 87.08%.

2. Group 2: Company Grade- (Cadet, Second Lieutenant, First Lieutenant, and Captain): This group was involved in 626 MVCs, of which 67 were fatal. These service members display the third highest proportion of 7.34% of the total fatal accidents, while permanent partial or total disability accidents accounted for 8.70% and 7.83%, respectively. However the risk of death is the highest of all groups at 10.70%. This characterizes them as the riskiest rank group.

3. Group 3: NCO- (Staff Sergeant, Technical Sergeant): Of the 3,197 MVCs for this rank group, 244 drivers lost their lives and their proportion of all fatal

MVCs is 26.73%. Furthermore, they displayed the second highest rate of permanent partial or total disability at 24.35% and 22.50% respectively. However, the risk rate for that group is relatively low, ranked fifth highest at 7.63%.

4. Group 4: Senior NCO- (Master Sergeant, Senior Master Sergeant, Chief Master Sergeant): This rank group displayed lower involvement in MVCs. In particular, of the 613 accidents for that period 56 individuals lost their lives accounting for 6.13% of all fatal accidents. However this rank group is second for the risk category due to 9.14% likelihood to die in MVCs, whereas, the risk of involvement in permanent and total disability accidents was 1.14% and 1.63%.

5: Group 5: Field Grade-(Major, Lieutenant Colonel, Colonel, and Brigadier General): This is the rank group with the lowest amount of MVCs. Specifically, 19 drivers died in 218 MVCs accounting for 2.08% of all fatal accidents. However, this rank group demonstrated the third highest risk, 8.72%, for being involved in a fatal MVC. They also experienced the greatest risk of PP disability at 1.38%.

Ultimately, the analysis reveals that severity of MVCs and rank are associated. The proportion of MVCs is disproportionally distributed among ranks, and, as Figure 27 portrays, Airman and NCO are associated with the majority of MVCs.

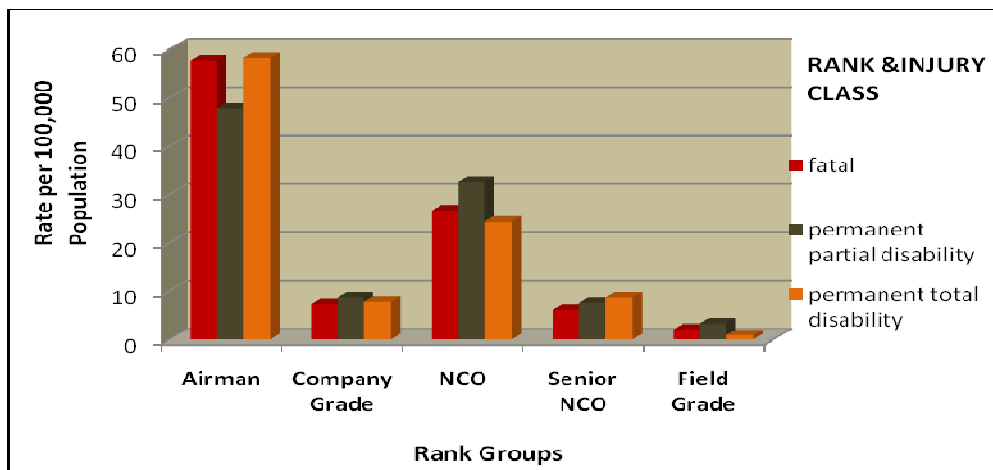


Figure 27. Fatal and Severe Injury Rates of USAF PMV Accidents per 100,000 Military Personnel by Rank, FY 1988-2009

However, the greatest fatality risk orientation is reflected between the ranks of Company Grade and Senior NCO described in Figure 28 below, followed by the Field Grade and Airman group. NCO group is related with the lowest fatality risk.

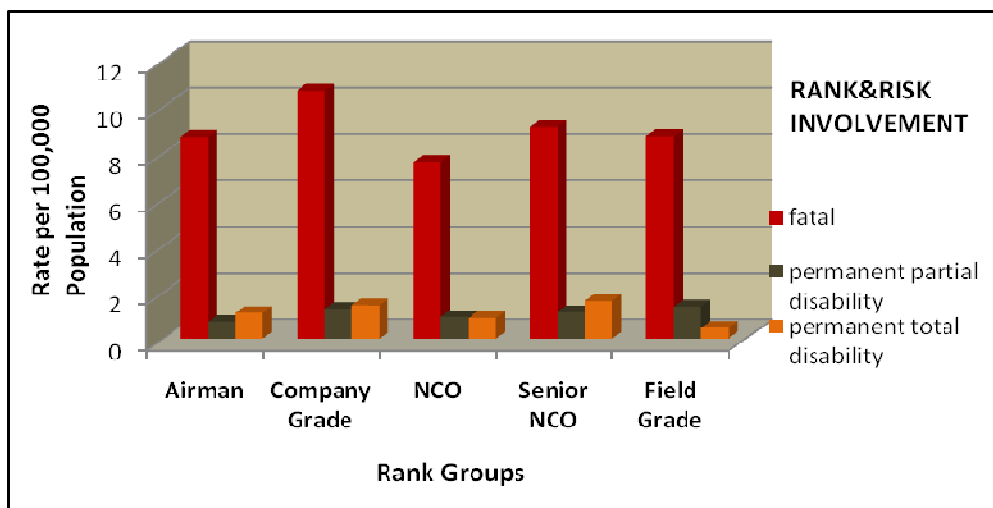


Figure 28. Percentage of Fatal and Severe USAF PMV Accidents by Rank per 100,000 Military Personnel FY 1988-2009

2. Whether the time of the day is associated with severity of MVCs.

Contingency Analysis of Injury Class by Time

Continuing the same statistic procedure, this thesis examines the broad range of time that MVCs occurred. The following histogram depicts the time distribution of MVCs for FY 1988 to FY 2009 demonstrating that the majority of MVCs occur between 0600-0800 and 1500-1900 hours, which is intuitive when considering that this is the heavily-traveled period when people usually travel to and from work.

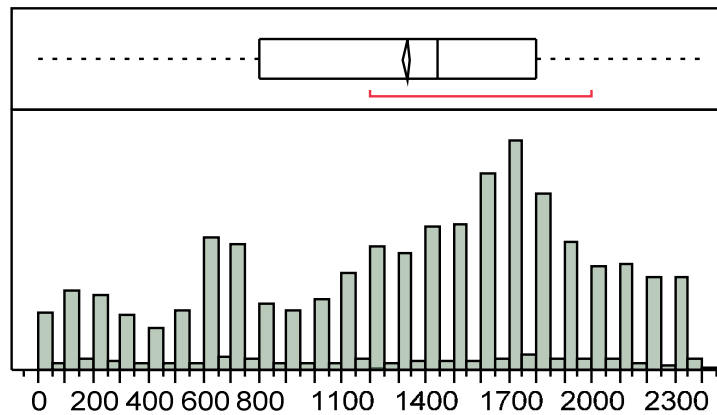


Figure 29. Histogram Time Distribution of USAF PMV Accidents FY 1988-2009

Table 9 below, is another tool this research employs to identify time groups with common characteristics. Minimum, median, and maximum time values of the MVCs are provided.

Table 8. Time Quantiles

100.0%	maximum	2400.0
99.5%		2345.0
97.5%		2315.0
90.0%		2100.0
75.0%	quartile	1800.0
50.0%	median	1445.0
25.0%	quartile	800.0
10.0%		330.0
2.5%		100.0
0.5%		11.6
0.0%	minimum	1.0

Considering the information of both the Figure 31 and the Table 10, this thesis employs a dummy variable that incorporates the following time groups with respect to the occurrence of MVCs.

- (i) Group 1: 0100-0400
- (ii) Group 2: 0500-0800
- (iii) Group 3: 1500-1800
- (iv) Group 4: 0900-1400 & 1900-2400

Through analysis, the Figure 30 below visually displays the association between injury class and time of the day due to the lack of uniform distribution. Here, the strength of the test is the $p\text{-value} < 0.0001$ that supports rejection of the null hypothesis. Given that evidence, the analysis concludes a disparity in the distribution of the time of day in which USAF military personnel have been involved in MVCs.

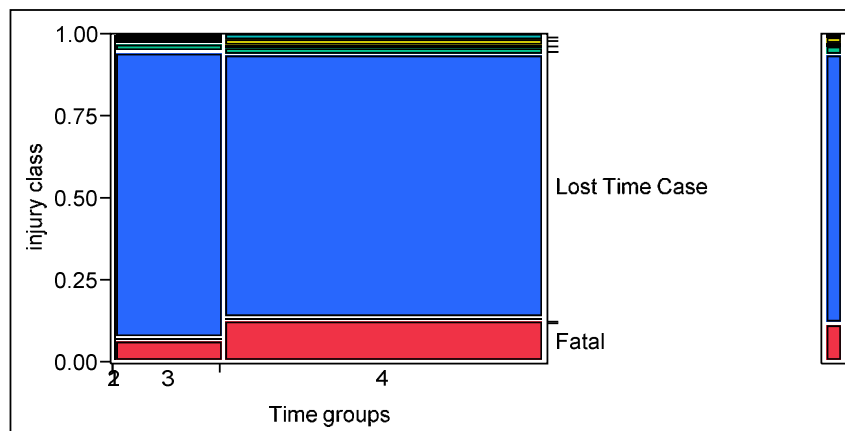


Figure 30. Mosaic Plot Injury Class by Time

Specific information related to that disparity is provided by the following contingency table.

Table 9. Contingency Table Injury Class by Time

Count Total % Col % Row %	Fatal	First Aid Case	Lost Time Case	Lost Time Hours	No Lost Time	Permane nt Partial Disability	Permanent Total Disability	Trea ted and Rele ased	
1. 1.0-4.0	4 0.05 0.44 21.05	1 0.01 7.69 5.26	14 0.18 0.22 73.68	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	19 0.25
2. 5.0-8.0	5 0.07 0.55 55.56	0 0.00 0.00 0.00	3 0.04 0.05 33.33	0 0.00 0.00 0.00	1 0.01 0.68 11.11	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	9 0.12
3 15-18	137 1.78 15.10 7.11	3 0.04 23.08 0.16	1684 21.92 26.60 87.44	0 0.00 0.00 0.00	52 0.68 35.37 2.70	20 0.26 21.74 1.04	20 0.26 17.54 1.04	10 0.13 12.9 9 0.52	1926 25.07
4 9-14& 19-24	761 9.91 83.90 13.29	9 0.12 69.23 0.16	4629 60.27 73.13 80.83	1 0.01 100.00 0.02	94 1.22 63.95 1.64	72 0.94 78.26 1.26	94 1.22 82.46 1.64	67 0.87 87.0 1 1.17	5727
Total	907 11.81	13 0.17	6330 82.41	1 0.01	147 1.91	92 1.20	114 1.48	77 1.00	7681

The majority of the 5,727 MVCs occurred between 0900-1400&1900-2400 hours, followed by the second critical time of the day, 1500-1800 hours,(1,926 MVCs), and 0100-0400 and 0500-0800 hours with 19 and 9 MVCs, respectively. The time periods with the highest frequency of fatal crashes are 0900-1400 and 19.00-24.00 hours, with a fatality rate of 83.90%, stands alone as the highest of every other period of time followed by 1500-1800 hours when the most people lose their lives as profiled by a 15.10% fatality rate. However, the most hazardous periods are 0500-0800 and 0100-0400 hours when the risk of drivers to lose their lives is 55.56% and 21.05%, accordingly. Therefore, this study concludes that while the majority of MVCs occur during the day and early evening, the most risky time is late at night and early in the morning. Figure 31 below confirms that the majority of MVCs occur during the day.

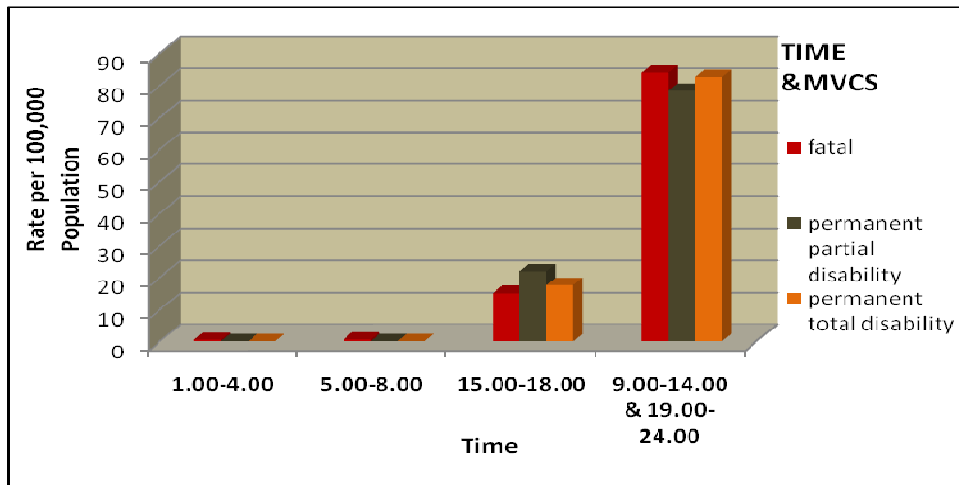


Figure 31. Fatal and Severe Injury Rates of USAF PMV Accidents per 100,000 Military Personnel by Time, FY 1988-2009

However, the fact that after midnight early and early in the morning is the most risky time for death depicted in Figure 32 below.

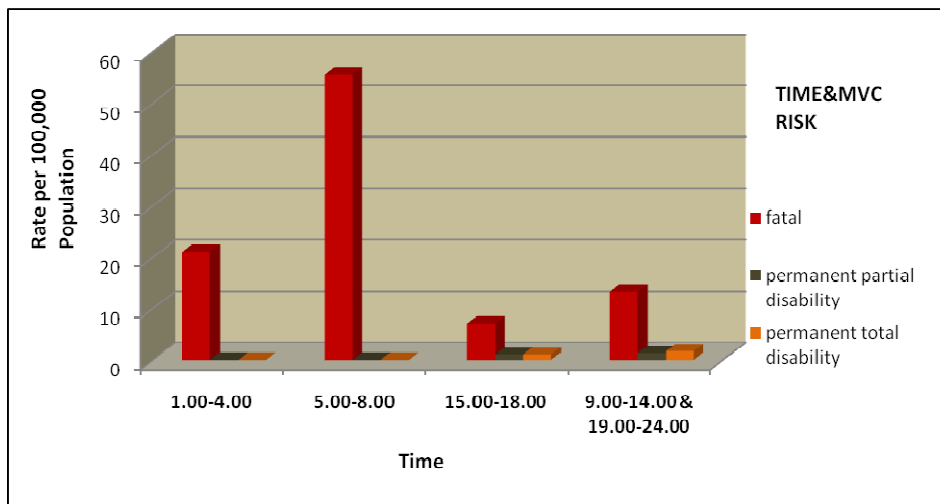


Figure 32. Percentage of Fatal and Severe USAF PMV Accidents by Time per 100,000 Military Personnel FY 1988-2009

3. Whether the type of vehicle (four-wheeled (4W), two-wheeled (2W)) is associated with the injury class of MVCs.

*Contingency Analysis of Injury Class by Type of Vehicle
(Four-wheeled (4W), two-wheeled (2W))*

The results of the analysis, as expressed by the mosaic plot, suggest dependency between severity of a crash and type of vehicle. In addition, this thesis takes into account p-value <0.0001, rejecting the null hypothesis and confirming the evidence of association.

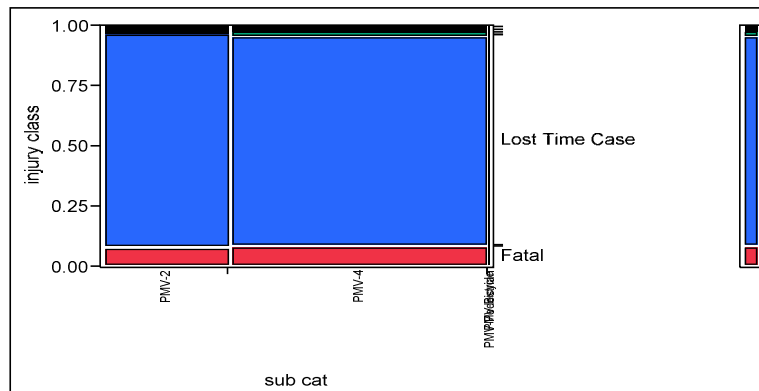


Figure 33. Mosaic Plot Injury Class by Type of Vehicle

The Contingency Table 10 provides in detail more useful information.

Table 10: Contingency Table Injury Class by Type of Vehicle

Count Total % Col % Row %	Fatal	First Aid Case	Lost Time Case	Lost Time Hours	No Lost Time	Permanent Partial Disability	Permanent Total Disability	Treated and Released	
PMV-2	292 2.73 31.98 8.24	2 0.02 15.38 0.06	3131 29.23 33.48 88.40	0 0.00 0.00 0.00	22 0.21 14.97 0.62	52 0.49 56.52 1.47	40 0.37 34.78 1.13	3 0.03 3.80 0.08	3542 33.06
PMV-4	620 5.79 67.91 8.67	11 0.10 84.62 0.15	6205 57.92 66.34 86.77	1 0.01 100.00 0.01	125 1.17 85.03 1.75	40 0.37 43.48 0.56	75 0.70 65.22 1.05	74 0.69 93.67 1.03	7151 66.75
PMV- Bicycle	1 0.01 0.11 5.88	0 0.00 0.00 0.00	15 0.14 0.16 88.24	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 0.01 1.27 5.88	17 0.16
Total	913 8.52	13 0.12	9353 87.31	1 0.01	147 1.37	92 0.86	115 1.07	79 0.74	10713

First of all, the proportion of USAF drivers who were involved in MVCs using 4W vehicles is higher than that of 2W vehicles. In fact, 7,151 of MVCs were using PMV-4W, accounting for 67.91% of total MVCs, as compared to 3,542 driving PMVs-2W, or 31.98% of accidents. However, PMV-2W drivers represent a majority 56.52% of permanent partial disability types of MVCs while, PMV-4W drivers measure 43.48%. On the contrary, drivers in PMVs-4W demonstrated the highest permanent total disability rate of 65.22% almost double that of PMV-2W.

It is pointed out that the fatality risk rate of every driver of both categories is almost identical, only 0.43% higher for drivers in PMV-4W. That means that even though there is association, both categories experienced approximately the same fatal MVC risk MVC. Figure 34, displays the higher proportion of fatal and PT disability MVCs associated with 4 W vehicles.

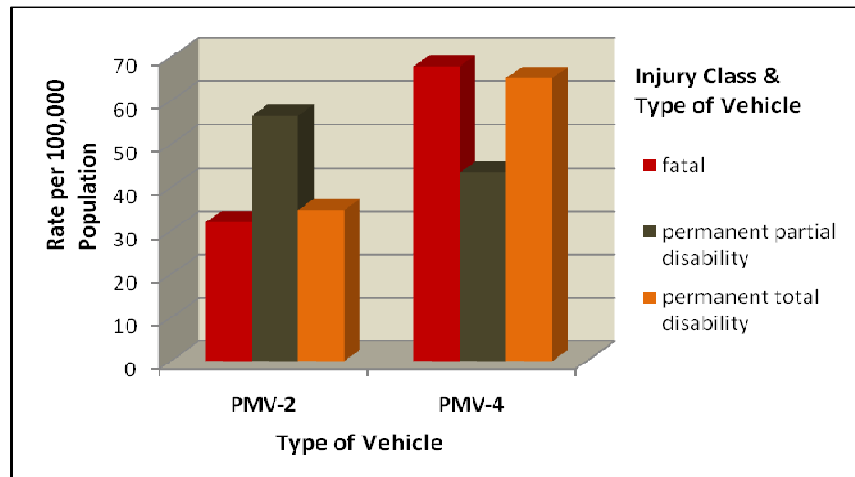


Figure 34. Fatality and Severe Injury Rates of USAF PMV Accidents per 100,000 Military Personnel by Type of Vehicle, FY 1988-2009

The likelihood of a 4W or 2W driver to die in a MVC is almost identical. However considering the smallest road traffic population of PMV2W, the evidence of road risk for them is uncountable as Figure 35 depicts.

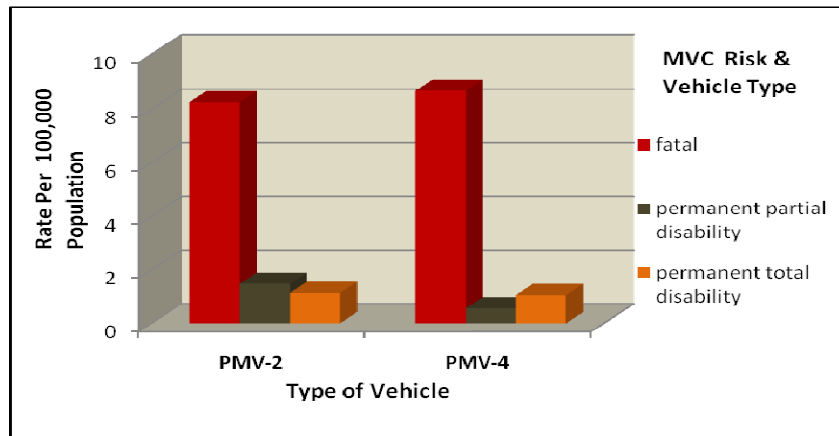


Figure 35. Percentage of Fatal and Severe USAF PMV Accidents per 100,000 Military Personnel by Type of Vehicle FY 1988-2009

3. Whether seatbelt usage is associated with the severity of MVCs

Contingency Analysis of Injury Class by Seatbelt Usage

Considering the relative mosaic plot, the analysis suggests that severity of MVCs and seatbelt usage are statistically dependent as reflected in the specific clearly demonstrated by the Figure 36 below. In addition, taking into account the evidence of $p\text{-value} < 0.0001$ this thesis rejects the null hypothesis and supports that injury class and seatbelt usage are statistically dependent.

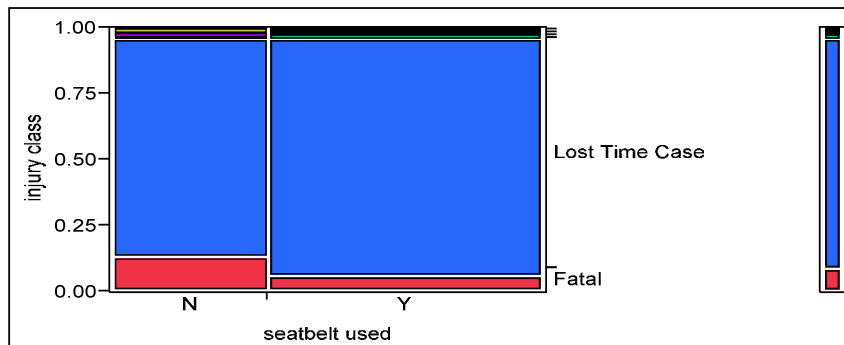


Figure 36. Mosaic Plot Injury Class by Seatbelt Usage

The contingency table, Table 12, provides useful information relative to the association. In particular, 6,370 drivers were involved in MVCs utilizing seatbelts

while 3,676 were not. Given the fact that an individual is involved in a fatal MVC, the proportion not using seatbelts is 56.24% as compared to 43.76% who buckled up.

Table 11. Contingency Table Injury Class by Seatbelt Use

Count Total % Col % Row %	Fatal	First Aid Case	Lost Time Case	Lost Time Hours	No Lost Time	Permane nt Partial Disabilit y	Perman ent Total Disabilit y	Treated and Releas ed	
N	487 4.85 56.24 13.25	0 0.00 0.00 0.00	3031 30.17 34.60 82.45	0 0.00 0.00 0.00	29 0.29 21.48 0.79	54 0.54 65.06 1.47	66 0.66 59.46 1.80	9 0.09 11.39 0.24	3676 36.5 9
Y	379 3.77 43.76 5.95	10 0.10 100.00 0.16	5730 57.04 65.40 89.95	1 0.01 100.00 0.02	106 1.06 78.52 1.66	29 0.29 34.94 0.46	45 0.45 40.54 0.71	70 0.70 88.61 1.10	6370 63.4 1
Total	866 8.62	10 0.10	8761 87.21	1 0.01	135 1.34	83 0.83	111 1.10	79 0.79	1004 6

Ultimately, drivers not using seatbelts experienced an extremely high fatality risk of 13.25% compared to 5.95% of the population wearing seatbelts. Furthermore, service men and women who fail to use seatbelts experienced more than twice the risk of permanent partial total disability. In fact, the risk of remaining permanently partially or totally disabled is 1.47% and 1.80%, respectively. Figure 37 below graphically displays the risk of both conditions.

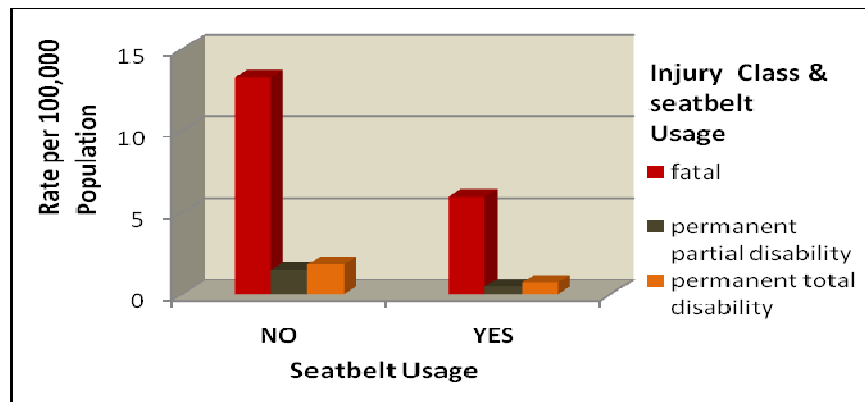


Figure 37. Percentage of Fatal and Severe USAF PMV Accidents per 100,000 Military Personnel by Seat Belt Use FY 1988-2009

Contingency Analysis of Injury Class by Alcohol Involvement

It is worth pointing out that this thesis takes into account the categorical variable of alcohol involvement and not the BAC level due to the large amount of missing data relative to the issue. This study approach gives the opportunity for better alcohol representation in the research. Considering the mosaic plot, Figure 38, the results confirm an association between alcohol involvement and severity of MVCs.

In spite of this, alcohol involvement does not appear to be related with the majority of MVCs, due to the fact that the likelihood of being involved in an alcohol related MVC is lower than that of one without alcohol involvement. However, alcohol influences the severity of a crash when present. In addition, $p\text{-value} < 0.0001$ is strong evidence of the association.

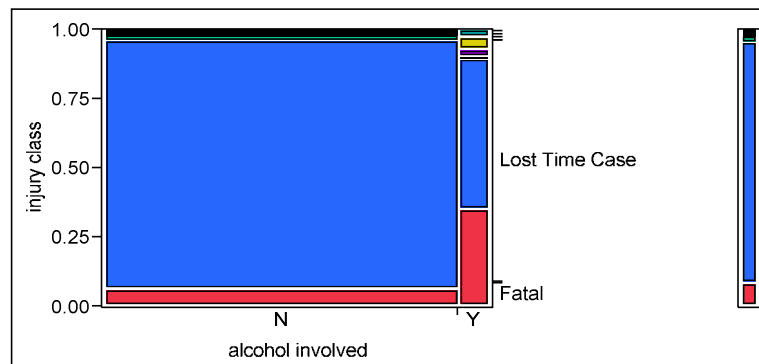


Figure 38. Mosaic Plot Injury Class by Alcohol Involvement

Table 13 helps illustrate the dramatic consequences of alcohol involvement. The majority of MVCs are not related to alcohol involvement; however, the risk of service members to die given the fact that they drink and drive is 35.36% compared to 6.34% of those without alcohol involvement. Furthermore, risk of permanent total disability is 4.34% when under the influence of alcohol, more than three times higher than that of no alcohol involvement. Similarly, the risk of permanent and partial

disability with respect to alcohol related MVCs is 2.43% compared to 0.73% when alcohol was not present.

Table 12. Contingency Table Injury Class by Alcohol Involvement

Count Total % Col % Row %	Fatal	First Aid Case	Lost Time Case	Lost Time Hours	No Lost Time	Permanen t Partial Disability	Permanent Total Disability	Treated and Released	
N	628	12	8915	0	144	72	80	58	9909
	5.86	0.11	83.20	0.00	1.34	0.67	0.75	0.54	92.48
	68.78	92.31	95.31	0.00	97.96	78.26	69.57	72.50	
	6.34	0.12	89.97	0.00	1.45	0.73	0.81	0.59	
Y	285	1	439	1	3	20	35	22	806
	2.66	0.01	4.10	0.01	0.03	0.19	0.33	0.21	7.52
	31.22	7.69	4.69	100.00	2.04	21.74	30.43	27.50	
	35.36	0.12	54.47	0.12	0.37	2.48	4.34	2.73	
	913	13	9354	1	147	92	115	80	10715
	8.52	0.12	87.30	0.01	1.37	0.86	1.07	0.75	

Figure 39 below depicts the negative influence of impaired driving and shows that the likelihood to die is nearly 30% higher than that of no alcohol involvement while risk of PT disability is 3.5% higher than with no alcohol involvement.

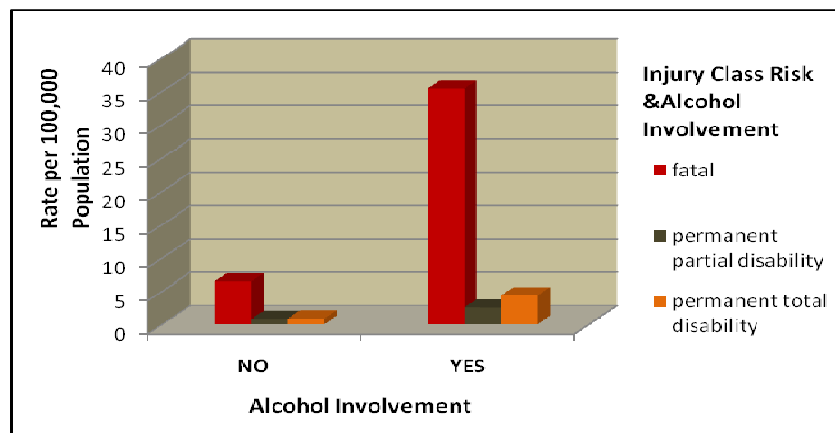


Figure 39. Percentage of Fatal and Severe USAF PMV Accidents per 100,000 Military Personnel by Alcohol Involvement FY 1988-2009

4. Whether Gender is associated with alcohol related MVCs.

Contingency Analysis of Alcohol Involvement by Gender

The distribution of the following mosaic in Figure 40, suggests that gender and alcohol, given a MVC, are statistically dependent. In addition, p-value <0.0001 is strong evidence to accept the alternative hypothesis of dependency.

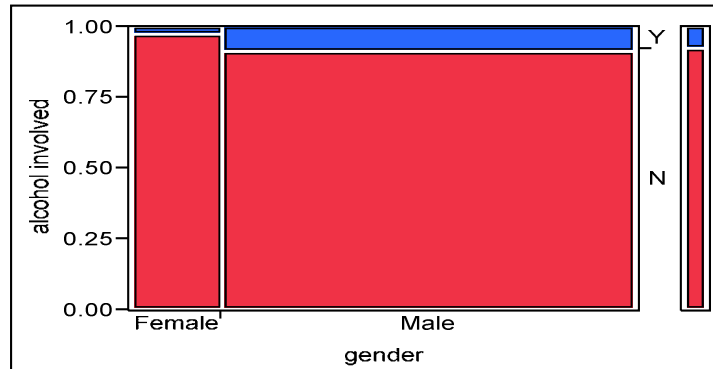


Figure 40. Mosaic Plot Alcohol Involvement by Gender

The association is demonstrated in detail in the Table 14 below. Specifically, 93.49% of all alcohol related MVCs involved male drivers, as compared to 6.51% female. However, the percent of crashes that are alcohol related is 8.88% for males and 2.76% for females.

Table 13. Contingency Table Alcohol Involvement by Gender

Count Total % Col % Row %	No Alcohol	Yes Alcohol	
Female	1939 17.80 19.30 97.24	55 0.50 6.51 2.76	1994 18.30
Male	8110 74.44 80.70 91.12	790 7.25 93.49 8.88	8900 81.70
Total	10049 92.24	845 7.76	10894

Figure 41 portrays the association relative to drinking and driving habits by gender.

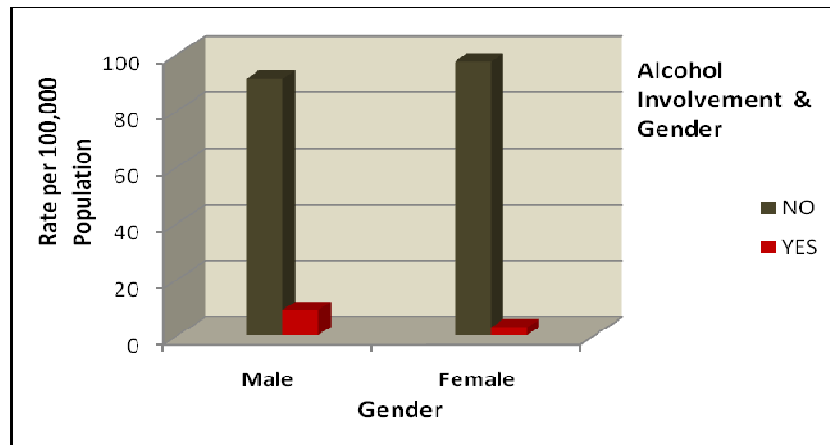


Figure 41. Percentage of Fatal and Severe Alcohol Related USAF PMV Accidents per 100,000 Military Personnel by Gender FY 1988-2009

6 Whether Rank of USAF military personnel is associated with alcohol related MVCs.

Contingency Analysis of Alcohol Involvement by Rank

This thesis attempts to identify whether the rank of USAF personnel is associated with alcohol related MVCs. As previously stated, the following levels applied for the military ranks.

- (i) Group 1: Airman- (Airman Basic, Airman, , Airman First class, Senior Airman)
- (ii) Group 2: Company Grade- (Cadet, Second Lieutenant, First Lieutenant, and Captain)
- (iii) Group 3: NCO- (Staff Sergeant, Technical Sergeant)
- (iv) Group 4: Senior NCO- (Master Sergeant, Chief Master Sergeant, Senior Master Sergeant)
- (v) Group 5: Field Grade- (Major, Lieutenant Colonel, Colonel, and Brigadier General).

The mosaic plot, Figure 42, visually determines an indication of dependency. Moreover considering the hypothesis test, $p\text{-value}=0.0005$ provides evidence to accept the alternative hypothesis that rank and alcohol related MVCs are statistically associated.

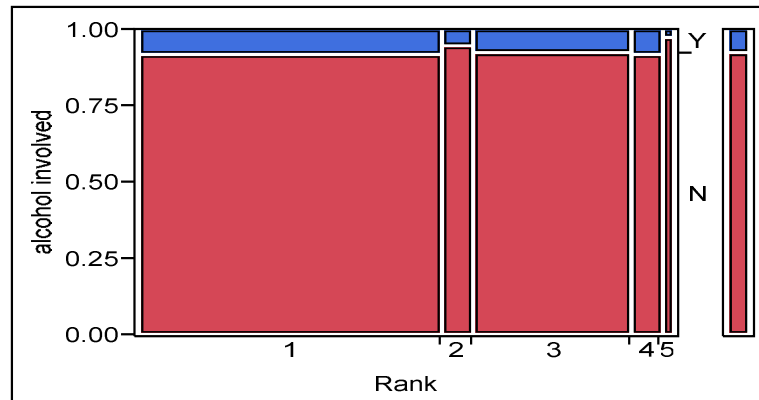


Figure 42. Mosaic Plot Alcohol Involvement by Rank

Table 15 below displays significant information about the correlation between rank group and alcohol involvement. In particular, the association is disproportional and depends on military rank despite the fact that the majority of MVCs were not under the influence of alcohol.

- Specifically, the group that demonstrates the highest proportion of impaired driving MVCs is the Airman group at 60.59%. This group is also responsible for the highest risk of alcohol related MVCs at 8.25%.
- The Senior NCO rank group was involved in 5.92% of alcohol related MVCs, however posed the second highest risk at 8.14% for being impaired and involved in a MVC while driving.
- As far as NCOs are concerned, their proportional alcohol related MVCs is 28.76% as the third riskiest ranked group at 7.54%

- Company Grade Officers were involved in 4.14% of all alcohol related MVCs and are the fourth risk ranked group of 5.50%
- Finally Field Grade officers demonstrate 0.59% involvement and 2.28% risk for involvement in alcohol related MVCs.

Table 14. Contingency Table Alcohol Involvement by Rank

Count Total % Col % Row %	No	Yes	Total
Airman	5692 52.25 56.64 91.75	512 4.70 60.59 8.25	6204 56.95
Company Grade	601 5.52 5.98 94.50	35 0.32 4.14 5.50	636 5.84
NCO	2978 27.34 29.63 92.46	243 2.23 28.76 7.54	3221 29.57
Senior NCO	564 5.18 5.61 91.86	50 0.46 5.92 8.14	614 5.64
Field Grade	214 1.96 2.13 97.72	5 0.05 0.59 2.28	219 2.01
	10049 92.24	845 7.76	10894

Ultimately, this thesis concludes association between rank and alcohol in MVCs, while the relative alcohol involvement and risk per rank group is shown in Figure 43.

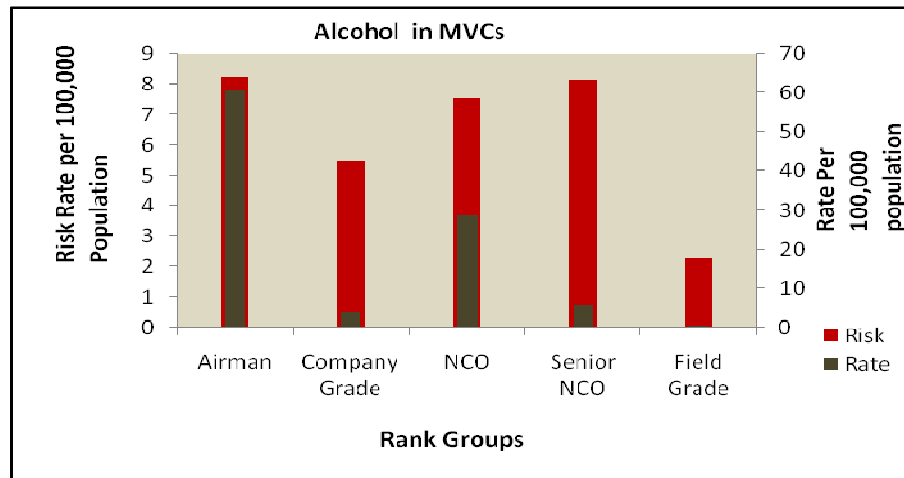


Figure 43. Percentage of Alcohol Related USAF PMV Accidents and Frequency per 100,000 Military Personnel by Rank, FY 1988-2009

7. Whether FY (Operations Tempo) is associated with Severity of MVCs

Contingency Analysis Injury Class of MVCs by FY

It was stated earlier that operations tempo is best analyzed by using the FY variable, because each year incorporates events such as deployments, training and the work environment of the AF. According to the following mosaic plot, Figure 44, a statistical association is visualized between FY and Injury class. Furthermore, testing the hypothesis of dependency, p-value <0.0001 indicates that there is strong evidence so as this study to confirm this association.

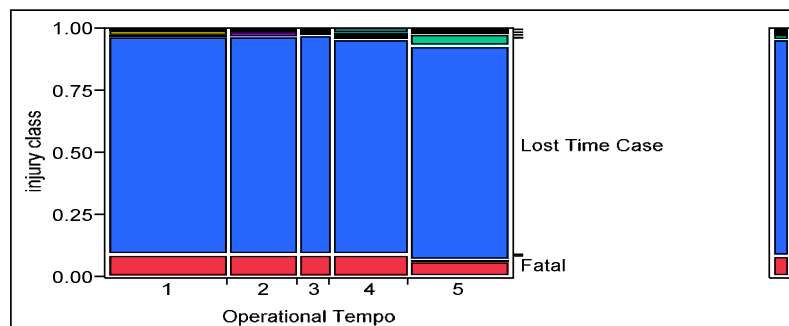


Figure 44. Mosaic Plot (I) Injury Class of MVCs by FY

Table 16 provides further details relative to the magnitude and type of association. Knowing that USAF personnel have been involved in MVCs, the severity of the crash is disproportionately distributed under specific circumstances for each time period below:

War

This category includes the periods of the Gulf War and invasion to Iraq and Afghanistan as well as peacekeeping forces in former Yugoslavia. Particularly, the risk for USAF service members to be involved in severe MVCs is dependent on the following conditions for these periods:

(i) During FY 2001- 2004, when the United States and Coalition Forces invaded Afghanistan and Iraq to fight terrorism, the proportion of all fatal accidents was the highest (20.92%) in contrast to any other period of high operations tempo. For the same period, service members experienced extensive involvement in permanent partial and total disability MVCs accounting for 15.22% and 18.26%, accordingly.

Later during FY 2005-2009, when the USAF was still engaged in war vs. Iraq and Afghanistan, activity for all fatal MVCs is lower than the early stages of the war, 18.07%. Furthermore, the relative amount of permanent partial disabilities from MVCs is higher than the early stages as compared to the lower risk of permanent total disability. These rates provide valuable information about diversities in operations tempo during the same event and their correlation with MVC severity.

(ii) The second influential time period with respect to injury class is FY 1989- 1991, during the US invasion of Panama and the Persian Gulf War. Those

periods share MVC fatalities of 18.95% while the proportion of permanent partial or total disability accidents was 1.28% and 1.17 %, respectively.

(iii) The least involvement with fatal MVCs was during the US share in the NATO peacekeeping force in the former Yugoslavia, during FY 1995-1996. In particular, the proportion of all fatal accidents that occurred during that time was only 8.76% while the relative amount of permanent partial or total disability MVCs was only a 7.61% and 8.70%, respectively. This is the lowest rate of the war timeline.

However the fatality risk, given a specific period, is disproportionately distributed. For example:

(i) Peacekeeping in former Yugoslavia, FY 1995-1996 - 9.37% is the highest of any other period

(ii) Panama-Gulf War, FY 1989- 1991 - 9.21%

(iii) Iraq- Afghanistan, FY 2001-2004 - 9.18%

(iv) Iraq-Afghanistan, FY 2005-2009 - 6.23%

Peace time

In peacetime periods FY 1988, 1992-94, and 97-2000, USAF personnel were involved in 3,253 MVCs which account for 33.30% of all fatalities, the second highest risk (9.35%) compared to the NATO peacekeeping commitment of 1995-96. In addition the proportion of permanent partial or total disability MVCs was 26.09% and 19.13%.

Table 15. Contingency Table (I) FY by Severity of MVCs

Count Total % Col % Row %	Fatal	First Aid Case	Lost Time Case	Lost Time Hours	No Lost Time	Permanen t Partial Disability	Permanent Total Disability	Treated and Released	
1	304 2.84 33.30 9.35	0 0.00 0.00 0.00	2853 26.63 30.50 87.70	0 0.00 0.00 0.00	0 0.00 0.00 0.00	22 0.21 23.91 0.68	48 0.45 41.74 1.48	26 0.24 32.50 0.80	3253 30.36
2	173 1.61 18.95 9.21	0 0.00 0.00 0.00	1650 15.40 17.64 87.86	0 0.00 0.00 0.00	0 0.00 0.00 0.00	24 0.22 26.09 1.28	22 0.21 19.13 1.17	9 0.08 11.25 0.48	1878 17.53
3	80 0.75 8.76 9.37	0 0.00 0.00 0.00	751 7.01 8.03 87.94	0 0.00 0.00 0.00	0 0.00 0.00 0.00	7 0.07 7.61 0.82	10 0.09 8.70 1.17	6 0.06 7.50 0.70	854 7.97
4	191 1.78 20.92 9.18	0 0.00 0.00 0.00	1808 16.87 19.33 86.92	0 0.00 0.00 0.00	18 0.17 12.24 0.87	14 0.13 15.22 0.67	21 0.20 18.26 1.01	28 0.26 35.00 1.35	2080 19.41
5	165 1.54 18.07 6.23	13 0.12 100.0 0	2292 21.39 24.50 86.49	1 0.01 100.00 0.04	129 1.20 87.76 4.87	25 0.23 27.17 0.94	14 0.13 12.17 0.53	11 0.10 13.75 0.42	2650 24.73
	913 8.52	13 0.12	9354 87.30	1 0.01	147 1.37	92 0.86	115 1.07	80 0.75	1071 5

As a result, this thesis concludes that injury class and instability in the work environment due to fluctuations of operations tempo are related. In fact, the severity of MVCs is disproportionally distributed from FY 1988 to FY 2009. Figure 45 below, graphically displays the results of the analysis.

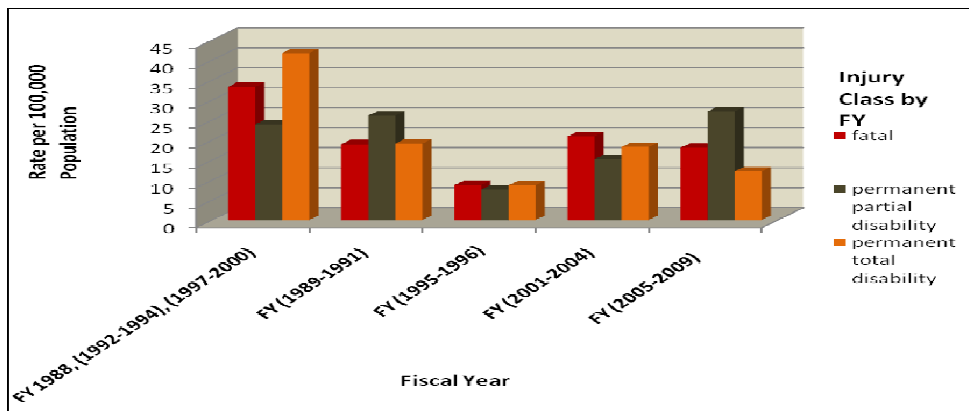


Figure 45. Fatality and Severe Injury Rates of USAF PMV Accidents per 100,000 Military Personnel by FY, FY 1988-2009

However, the relative risk depicted below in Figure 46, revealed that peace time is risky too.

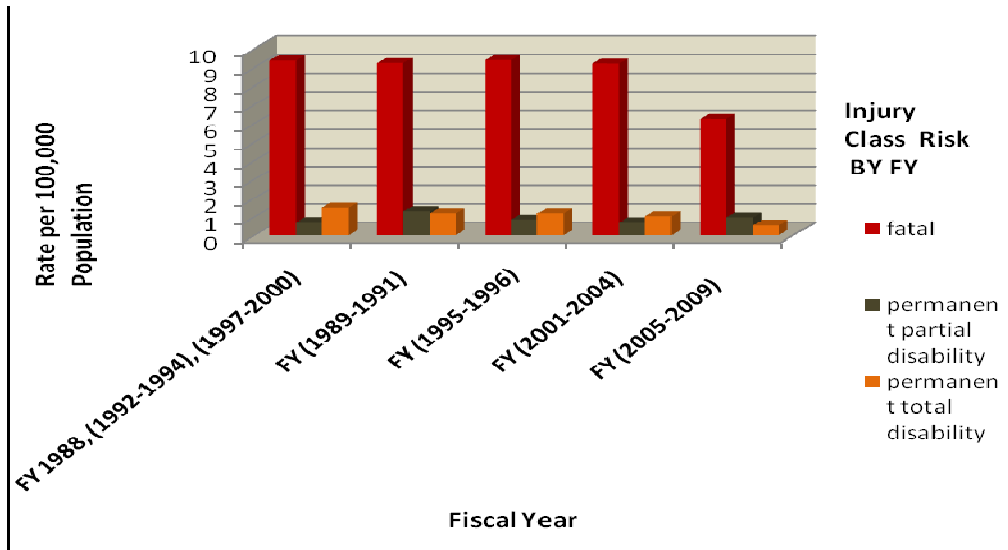


Figure 46. Percentage of Fatal and Severe USAF PMV Accidents per 100,000 Military Personnel by FY, FY 1988-2009

The second approach of this thesis is to investigate the influence of FY on war timelines, as a comparison of the severity of MVCs during times of war and peace for USAF operations. In particular, the dummy variable incorporates FY groups, relative to events with common characteristics for each year. The following scheme code applies:

- (i) 1: Fiscal years with low operations tempo (Peace time: FY 1988,1992-94, 97-2000)
- (ii) 0: Fiscal years with high operations tempo (War: the remaining period of the study)

According to the mosaic plot, Figure 47, this thesis suggests that periods with a high pace of operations and severity of MVCs are statistically dependent. In addition, considering the $p\text{-value} < 0.0001$, the analysis accepts the alternative hypothesis of dependency.

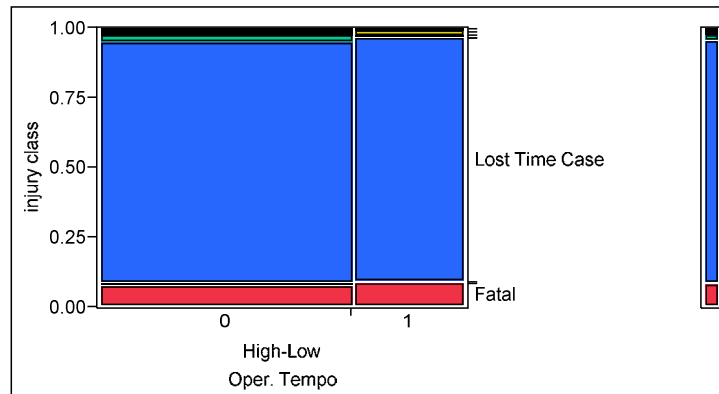


Figure 47. Mosaic Plot (II) Severity of MVCs by FY

Furthermore, Table 17 provides a total view of the consequences of each FY period for private MVCs for the same comparative analysis. Specifically, the proportion of USAF personnel in fatal crashes during periods of high pace operations is 66.70% as the fractions 76.09% permanent partial or 58.26% total disability type of MVCs are similarly representative of wartime involvement.

Conversely, these rates follow a downward trend during low paced operations 33.3% for fatal accidents and 23.91% and 41.74% for permanent partial or total disability, respectively.

However, the most risky period for a crash fatality is during low work load 9.35% as compared to 8.16% high paced operations.

Table 16. Contingency Table (II) Severity of MVCs by FY

Count Total % Col % Row %	Fatal	First Aid Case	Lost Time Case	Lost Time Hours	No Lost Time	Permane nt Partial Disability	Perman ent Total Disabilit y	Treat ed and Releas ed	
High OT	609 5.68 66.70 8.16	13 0.12 100.00 0.17	6501 60.67 69.50 87.12	1 0.01 100.00 0.01	147 1.37 100.00 1.97	70 0.65 76.09 0.94	67 0.63 58.26 0.90	54 0.50 67.50 0.72	7462 69.64
Low OT	304 2.84 33.30 9.35	0 0.00 0.00 0.00	2853 26.63 30.50 87.70	0 0.00 0.00 0.00	0 0.00 0.00 0.00	22 0.21 23.91 0.68	48 0.45 41.74 1.48	26 0.24 32.50 0.80	3253 30.36
	913 8.52	13 0.12	9354 87.30	1 0.01	147 1.37	92 0.86	115 1.07	80 0.75	10715

This thesis concludes that periods of high pace operations have dramatic consequences on the severity of MVCs when USAF personnel are involved as drivers. However, peace time periods are risky too given the fact that accidents occur with fatality risk of 9.35% compared to war time of 8.16%. However, the investigation of the evidence whether the high risk is due to leisure activities or to post traumatic stress is beyond the scope of this thesis. Figure 50 displays the results of the analysis specifically, that the greatest proportion of MVCs occurs during periods with high work load.

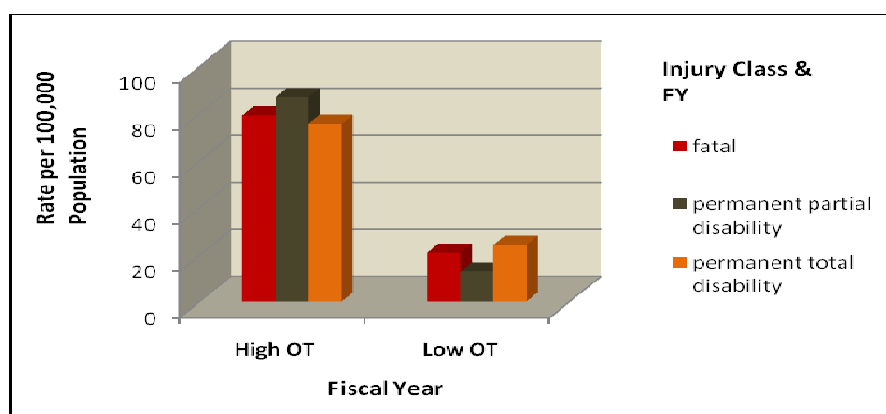


Figure 48. Fatality and Severe Injury Rates of USAF PMV Accidents per 100,000 Military Personnel by FY with High-Low Operations Tempo FY 1988-2009

However, peacetime periods demonstrate higher fatality risk as depicted in

Figure 49 below.

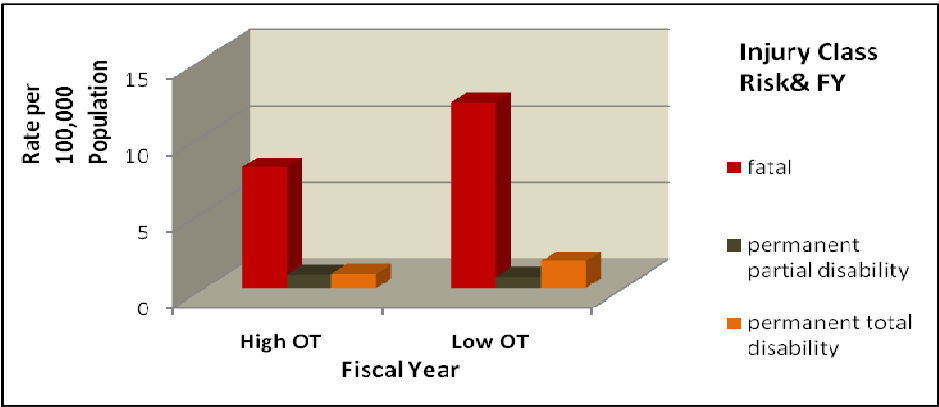


Figure 49. Percentage of Fatal and Severe USAF PMV Accidents per 100,000 Military Personnel by FY with High-Low Operations Tempo, FY 1988-2009

Contingency Analysis of Alcohol Involvement by FY in a Given MVC

The effort of this thesis is to expand and explain the influence of specific conditions that occur during this period by testing the association of FY and alcohol involvement in a given MVC. This might explain why peace time periods are risky with respect to severity of MVCs.

According to the mosaic plot it is visually possible to identify dependency.

The fact that $p\text{-value} < 0.0001$ is strong evidence to support this association.

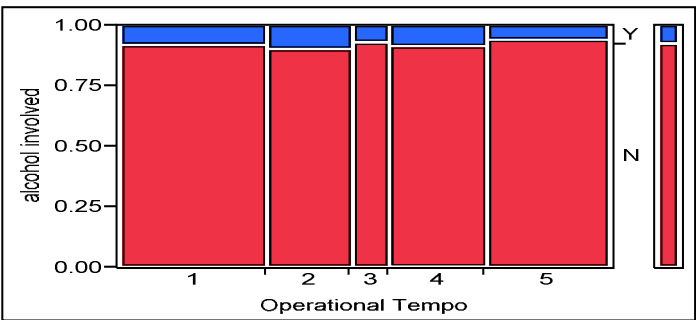


Figure 50. Mosaic Plot Alcohol Involvement by FY

Table 18 demonstrates the association of FY and alcohol involvement in a given MVC. In particular, alcohol related MVCs are disproportionately distributed, the range of which is defined during the periods below. More specifically, from all MVCs that occur in each period the likelihood to be alcohol related depends on the following circumstances and displays the relative risk rates:

- (i) Gulf War 9.47%
- (ii) Iraq-Afghanistan (early stage of the war) 8.71%
- (iii) Peace 7.87%
- (iv) Peace keeping in former Yugoslavia 6.79%.
- (v) Iraq-Afghanistan (2005-2009) 5.98%

The analysis shows that while alcohol involvement in a given MVC is associated with periods with high work load, during peace time alcohol involvement remains high but not equivalent to levels of high paced operations.

Table 17. Contingency Table Alcohol Involvement by FY

Count Total %	No	Yes	
Peace	3033 27.84 30.18 92.13	259 2.38 30.65 7.87	3292 30.22
Gulf War	1712 15.72 17.04 90.53	179 1.64 21.18 9.47	1891 17.36
Former Yugoslavia	796 7.31 7.92 93.21	58 0.53 6.86 6.79	854 7.84
Iraq- Afghanistan	1961 18.00 19.51 91.29	187 1.72 22.13 8.71	2148 19.72
Iraq- Afghanistan	2547 23.38 25.35 94.02	162 1.49 19.17 5.98	2709 24.87

Impaired driving as shown in Figure 51 was higher during periods of Gulf War and invasion of Iraq-Afghanistan. However peacetime FY 1988, 1992-94, 97-2000 is the third riskiest period that drivers demonstrate drinking and driving habits.

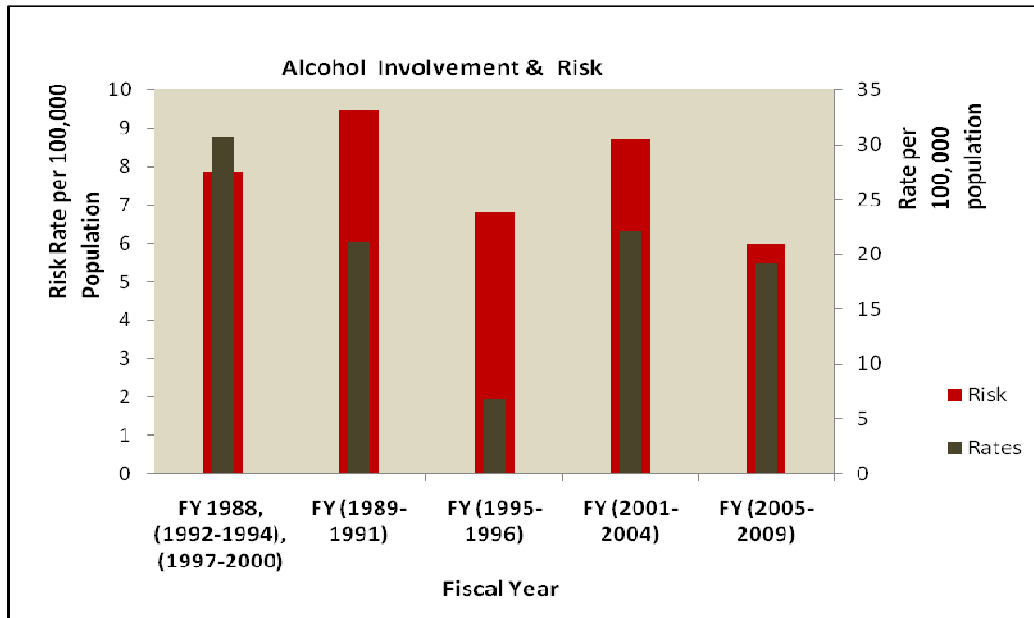


Figure 51. Percentage of Alcohol Related USAF PMV Accidents and Frequency per 100,000 Military Personnel by FY with High-Low Operations Tempo, FY 1988-2009

Contingency Analysis of Rank by FY in a Given MVC

Continuing the same concept with respect to FY discrimination (peace-war), this thesis conducted the association of Rank and FY in a given MVC. According to the Mosaic plot, Figure 52, it is suggested that there is dependency. The $p\text{-value} < 0.0001$ of the test supports the alternative hypothesis and the analysis concludes that rank and FY (operations tempo) are associated in a given MVC.

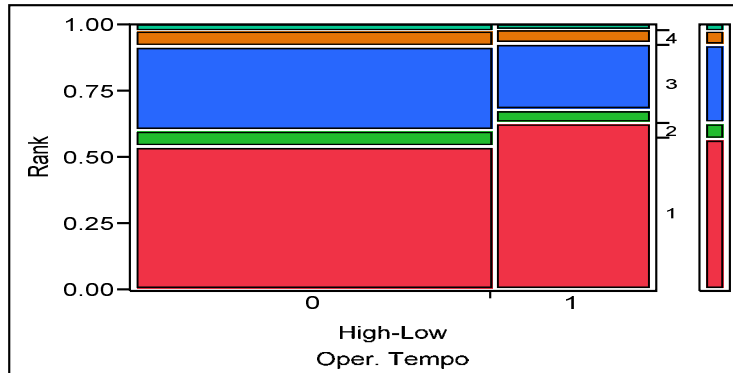


Figure 52. Mosaic Plot Rank by FY

In particular, it is demonstrated that the majority of MVCs are during periods with increased work load. 54.34% of those accidents involve the Airman category while 31.65% are from the NCO category. Moreover, during periods with heavy work load, Company Grade Officers rated 6.05% and Senior NCOs 5.79%, while only 2.17% of Field Grade Officers were implicated in those accidents.

Discriminating the risk for each group to be involved in a severe MVC during this period the following rates display how FY with high operations tempo influence each rank group. The following rates show the proportion of MVCs that each group had been involved during war compared to the total MVCs of the specific rank group.

1. Airman: (Airman Basic, Airman, Airman First Class, Senior Airman) 66.59%
2. Company Grade: (Cadet, Second Lieutenant, First Lieutenant, and Captain) 72.33%
3. NCO: (Staff Sergeant, Technical Sergeant) 74.70%
4. Senior NCO: (Master Sergeant, Senior Master Sergeant, and Chief Master Sergeant) 71.66%
5. Field Grade: (Major, Lt Col, Col, Brig General) 75.34%

It is more than impressive that high operations tempo affects higher ranks as illustrated by the top ranking of Field Grade Officers. On the contrary, Airmen are affected the least. This evidence might explain the higher risk relative to the severity of MVC during peace time considering the high percentile of USAF personnel represented by that rank group.

Table 18. Contingency Table Rank by FY

Count Total % Col % Row %	Airman	Company Grade	NCO	Senior NCO	Field Grade	
High OT	4131 37.92 66.59 54.34	460 4.22 72.33 6.05	2406 22.09 74.70 31.65	440 4.04 71.66 5.79	165 1.51 75.34 2.17	7602 69.78
Low OT	2073 19.03 33.41 62.97	176 1.62 27.67 5.35	815 7.48 25.30 24.76	174 1.60 28.34 5.29	54 0.50 24.66 1.64	3292 30.22
	6204 56.95	636 5.84	3221 29.57	614 5.64	219 2.01	10894

In conclusion, Figure 53 below shows the consequences of FY with respect to conditions in the work environment on each rank group, affecting first Field Grade Officers followed by, in decreasing order of impact, NCOs, Company Grade, Senior NCOs and Airman.

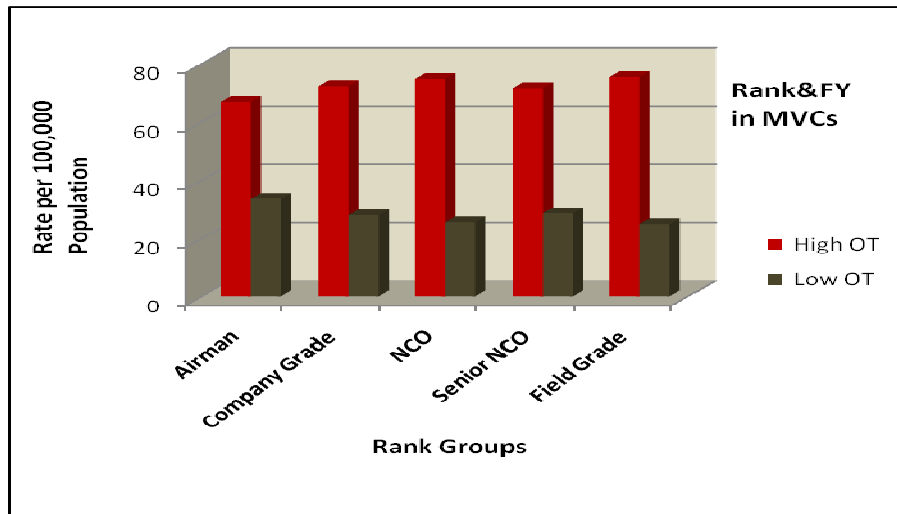


Figure 53. Percentages of USAF PMV Accidents per 100,000 Military Personnel, Rank by FY with High-Low Operations Tempo, FY 1988-2009

Multiple Regression

2nd Policy Objective

The second stated objective of this research was to identify the factors that are associated with the number of MVCs which influence direct cost and cause significant financial burden to the USAF budget. As described in Chapter III, every potential variable is investigated to explain the frequency of MVCs.

Analysis of the data reveals that the Y response is normally distributed. The histogram of MVCs depicted in Figure 54 below, illustrates the normal distribution of MVCs, with a slightly right skew, translating into no potential problem that might affect or reduce the overall fit of the model.

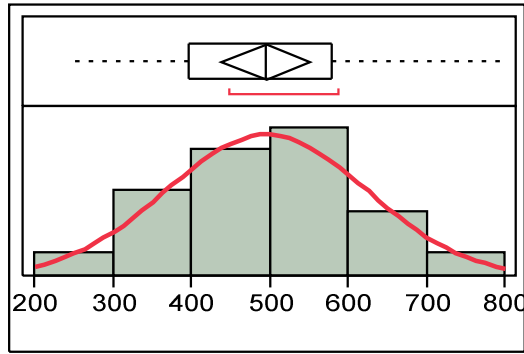


Figure 54. Histogram of MVCs

Predictor Variables- ANOVA Results

Appendix B, depicts the variables that are significant at a 0.05 confidence level to predict MVC volume through the use of diagrams that provide the linear fit of the response. The dots in the diagrams represent the actual response while the line shows the response that the variable predicted. A perfect fit would have all the dots on the line, indicating the predictability of the variable. The slope of the line shows either the negative or positive impact of the predictor variable to the response. Within the plots, the relative P-value, R^2 , R^2 (adj) are also presented.

Regression Model

This study presents the following model to explain the volume of MVCs with three predictor variables. Taking into account that the ratio of data points usually appear to be 10 to 1, every potential model can include no more than three variables. In addition, there is always the risk of model over fitting in spite of the fact that, by adding more variables, R Square (adj) can be increased. Besides, the addition of more and more variables does not always mean higher predictability. However, this research investigated more than three variables that are significant predictors. As it is

impossible to capture every individual influence on the dependent variable, it is necessary to at least collect the most influential.

The effort of this thesis is to provide a regression model that is relatively simple, effective and easy to interpret but not so oversimplified as to ignore significant influences. The regression results summarize the information contained in the data and do not imply causation. In particular the scatter plots, correlations, and regression equations can only provide supportive evidence of a potential association (Newbold et al, 2010: 11).

Model Description

Figure 55 below depicts the final model that displays coefficient of determination R Square-(Adj) of 0.992 and P-value<0.0001, while the actual by predicted plot reveals visually the quality of fit.

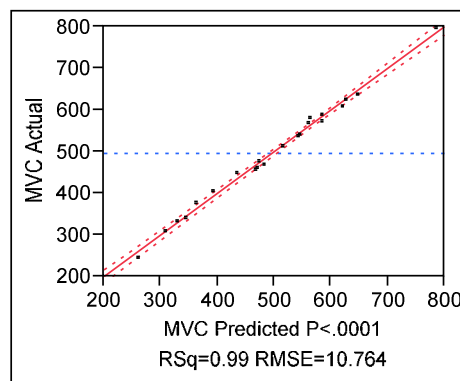


Figure 55. Actual by Predicted Plot

The final model employs three independent nominal variables that appear to be significant at $\alpha=0.05$ level of significance.

- (I) Male
- (II) Age (31-35)

(III) FY

The model response equation is:

$$\text{Amount of MVC} = -4.00 + 1.09 * (\text{Male}) + 0.71 * (\text{Age31-35}) + 2.07 * (\text{FY}).$$

In addition, the relative impact of every variable is represented by the following standardized beta coefficients making it obvious that the dominant variable is male gender, followed by age (31-35). Given the fact this model utilizes these two predictor variables, FY appears less significant.

(i) Male: 1.004

(ii) Age (31-35): 0.109

(iii) FY: 0.104

The parameter estimates show that all predictors have positive influences on the number of MVCs. In particular, for every male in the USAF, the total amount of MVCs increases by 1.09, while for every service member at that age group the total volume of MVCs increases by 0.71. In addition, for every additional year the number of MVCs increases by 2.07.

Diagnostics

Diagnostics tests were conducted for the model to ensure that the assumptions of Ordinary Least Squares (OLS) regression were met. Auxiliary diagnostic tests were also instituted to identify multicollinearity and influential data points or potential outliers.

Multicollinearity

Multicollinearity is when the independent variables are correlated. The Variance Inflation Factor (VIF) is used to test the correlation among the predictors, and, as it is presented below, VIF scores are very low. Owing that all the values are lower than five this study concludes there is no evidence of multicollinearity.

- (i) Male: VIF=1.02
- (ii) Age (31-35): VIF=1.84
- (iii) FY: VIF=1.82

Influential Data Points-Outliers

Influential data points and outliers are observations that extensively influence the overall outcome of the model. The Cook's Distance (Cook's D) overlay plot is engaged to identify data points with Cook's D values greater than 0.25 that might have significant impact on the model. The overlay plot below, Figure 56, indicates there are two potentially influential data points (observations 1 and 3) with Cook's D of approximately 0.4. In order to detect their impact, these points had to be excluded and the model re-run. The results are identical with $p\text{-value} < 0.0001$, implying that their absence would not have affected the analysis. As a consequence, these data points were included for the remainder of the analysis.

In addition, the dispersion of the data points within the plot subjectively indicates a desired level of randomness. Again, the benefit of not having influential data points is that the model is not overly directed by a single or a few number of observations.

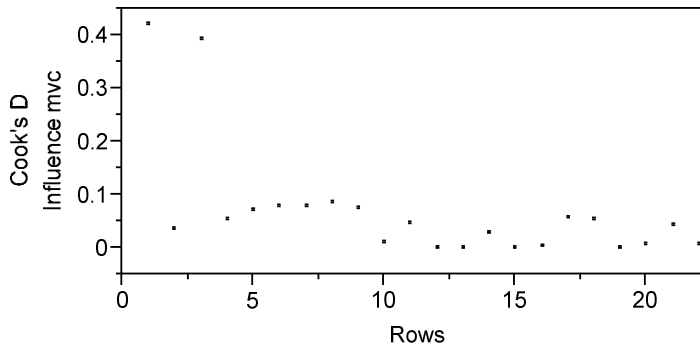


Figure 56. Overlay Plot of Cook's Distances

The plot of studentized residuals Figure 57, contributes to the analysis to assess whether there are potential outliers. Two types of outliers exist. Minor outliers are defined as observations ± 3 standard deviations from the mean, while major outliers represent ± 4 standard deviations from the mean. The plot of the studentized residuals below shows the number of standard deviations away from the mean. As no observations were more or less than 2 standard deviations from the mean, it is assessed that the model does not includes any outliers.

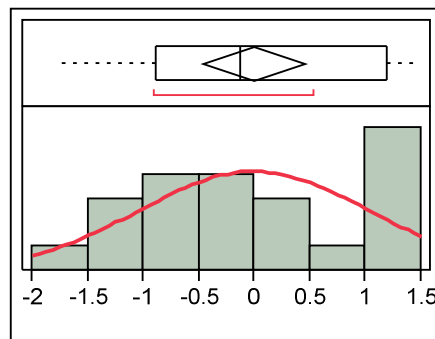


Figure 57. Studentized Residuals of MVC

Normality

The final model meets the OLS assumption of normality as depicted in Figure 58. The residual by predicted plot reveals pure 'white noise' that visually indicates normality.

Residual by Predicted Plot

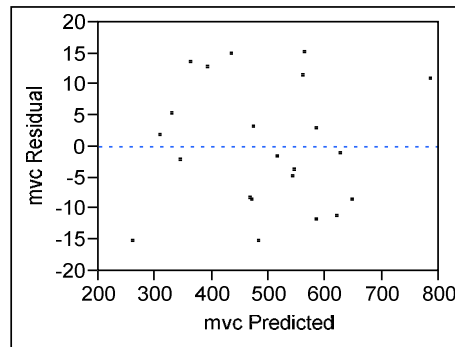


Figure 58. Residuals by Predicted Plot

Furthermore, normality can be tested by the Shapiro-Wilk (S-W) goodness-of-fit test. In fact this study employs the $p\text{-value}=0.1614$ in order to reject the null hypothesis (H_0) at the $\alpha=0.05$ significance level. As a result, it is concluded that the distribution of the residuals is not statistically different than a normal distribution as revealed in Figure 59 above.

Constant Variance

Ultimately constant variance is addressed with the Breusch-Pagan (B-P) test. Specifically, this study failed to reject the null hypothesis (H_0) at the $\alpha=0.05$ significance level with a $p\text{-value}=0.793$. This means that statistically the residuals exhibit constant variance.

Table 19. Breusch-Pagan Test

	Input			
SSR	18573.91		Test Stat	1.033491
SSE	2085.48		P-value	0.793149
N	22			
df (reg)	3			

Due to small sample size, this study employed the entire database to build the regression model without leaving a portion of the data against which to validate.

V. Conclusions and Recommendations

Research Objectives

This thesis demonstrates efforts undertaken to expand research relative to private MVCs involving USAF military personnel that address both injury classification and frequency of MVCs. Specifically, the objectives were to identify factors that influence the severity of injuries, as well as correlations among environmental conditions and impaired driving associated with other parameters that induce the injury class. To be concise, this study attempts to investigate factors that affect and explain the number of MVCs, as well as the relative total injury cost.

Methodology Review-Limitations

Prior research treated this topic differently as conducted the data with a different approach utilizing different variables and methodology, which is further described in Chapter II. However, this research deals with individual variables, to explore their impact on the objectives of the above paragraph. To this end, incorporating standard statistical techniques derive a regression model representative of the correlated selected independent variables to the response variable including discussion of model accuracy and meaning.

In particular, this thesis focused on private MVCs where USAF military personnel were involved as drivers. The endeavor was to identify and capture the influence of each factor on the driver to address the stated research objectives. The method, described in Chapters III and IV, awarded the analysis with another perspective from previous research incorporating the influence of alcohol, and FY in terms of political and societal conditions, as well as modeling the frequency of MVCs. However, the research was constrained by inconsistencies, and missing data.

The data show that the majority of car accidents occur when people are driving to and from work. Removing duplicates, the distribution of MVCs throughout this period indicates a specific trend that can be explained by the analysis. Furthermore ‘alcohol involvement’, rather than BAC, provides a better representation of alcohol’s effects on the analysis. Additionally, this thesis addresses the issue of operations tempo and its effects on alcohol usage and MVCs. Finally, modeling the number of MVCs can further highlight the financial burden they have on the USAF budget.

Thus, the analysis of this thesis seeks to discover statistical associations from historical data using Categorical Data Analysis and regression techniques. As far as the multiple regression analysis is concerned, the database is extracted from the historical data with the result that the Y-response is normally distributed and hence, no potential problem affects or reduces the overall fit of the model. The issue of military rank is distinguished by response tests by stratum as defined in Chapter III.

The fact that statistical analysis explains association and not causality makes it complicated to differentiate or isolate answers to the research questions. However, through a comprehensive well documented analysis this thesis attempts to provide information discussed later in this chapter.

Conclusions of Research

Despite declining numbers of the military personnel paired with the fact that prevention measures and campaigns have improved, MVCs do not display a downward trend. Similarly, they do not show significant improvement beyond the general decline of MVCs demonstrated in the past decade in the US at large.

Categorical Data Analysis Results

The outcome of the categorical data analysis is presented by each predictor variable considering the large number of investigative questions.

Injury Class by Gender

It is revealed that MVCs are disproportionally distributed between males and females. In particular, male gender displays extremely higher involvement than females. This outcome is logical since the amount of males and females in the Air Force is not identical. By extension, USAF male drivers had almost twice the probability of either dying or sustaining permanent partial or total disability than did USAF female drivers. This also confirms the literature and explains why male drivers suffered more severe injuries than those involved female drivers.

Injury Class by Age

This thesis identified that USAF military personnel, according to their age, had been disproportionally involved in severe MVCs. In particular, the majority of fatal MVCs were drivers 21-25 years old, followed by the 26-30 and 17-20 age groups. Drivers over 40 were the least involved.

Apart from that, every age group experienced risk to die irrespective of their involvement in MVCs. Specifically, whereas individuals 21-25 demonstrated higher association with fatal accidents, the risk of being involved in such a type of accident was higher for 17-20 year olds. This is the most risky age, according to the literature, and confirms the recommendation that teens should be the target of all prevention efforts followed by 26-30 year olds, and 21-25 year olds the third group most at risk.

The risk of suffering permanent total or partial disability is higher for individuals older than 20 with the highest risk experienced by the 31-35 age group.

Injury Class by Rank

The data shows that the USAF members in the rank category of Airman (i.e., Airman Basic, Airman, Airman First Class, and Senior Airman) have been involved in the majority of fatal, permanent partial or total disability accidents. These results might be related with the young age of the typical Airman for reasons presented above. NCOs were involved in the second higher proportion followed by Company Grade Officers who claimed the third highest proportion of fatal MVCs. Senior NCOs ranked the lowest for this category.

Apart from the fact that, the highest fatality rate is reported by the Airman group, the riskiest are the Company Grade Officers followed by the rank of Senior NCOs. This evidence might be explained by the influence of other factors such as work environment, pace of operations or alcohol involvement, since all of them correlated dissimilarly with the military ranks as presented in the next paragraphs.

Based on the categorical data analysis, Airmen were significantly related to impaired driving as were Senior NCOs. On the other hand, NCO, Company Grade and Field Grade ranks were influenced by periods with high operations tempo.

In conclusion, while a case for common and logical inference could be made with respect to the study of MVCs, the unpredictable military climate alters the balance of relative road traffic risk factors and their influence on service members.

Injury Class by Time

According to this study, the majority of severe crashes took place between 0900-1400 & 1900-2400 hours following the period 1500-1800 hours, when people are traveling to and from work. That makes sense, in light of the fact that most people

are on the road at that time, hence, the higher the proportion of the most severe MVCs as opposed to night and early in the morning (after 2400) hours which is the most risky and hazardous period for travel. In particular, the most risky time for USAF personnel to be involved in a severe MVC is between 0500-0800 & 0100-0400 hours. This evidence demonstrates the tendency for drivers to take more risks when driving at nighttime.

Injury Class by Vehicle

4-W vehicles are overwhelmingly implicated in more MVCs than two wheelers. This is logical because 4-wheel drivers are in the majority. However, based on AFSC data, USAF drivers share approximately the same risk of fatal MVCs regardless of whether they drive either a 4-W or a 2-W vehicle. However, two-wheeled suffered more permanent partial disabilities than 4-W drivers. This evidence is consistent with the literature because motorists who are not protected by their vehicle are exposed to higher risk. The exposure level to road traffic risks by type of vehicle confirms that 2-W drivers experienced extremely high fatality risk comparing their lower representation of licensed drivers.

Severity of Crash by Seatbelt

Seatbelts are one of the most critical occupant protection systems. As a consequence, seatbelt usage has a significant effect on the Type of Injury. In particular, while the majority of drivers buckle up, the most fatal and severe accidents occur when those drivers fail to do so. Similarly, unbelted USAF drivers have a higher risk of sustaining permanent partial or total disabilities than those who are belted at the time of the MVC.

Injury Class by Alcohol involvement

Out of consideration for inconsistencies, missing data, as well as the fact that blood alcohol tests are not uniformly conducted, this thesis uses the variable 'alcohol involvement', not BAC. Blood alcohol tests are performed only in some incidents, but almost certainly for those in which suspicion is warranted that the driver is impaired.

The majority of MVCs are not alcohol related. However, drivers experience a much higher risk to die or sustain PP or PT disability when driving under the influence of alcohol. From all alcohol related MVCs, the likelihood of a fatal or PT disability type of accident was nearly 30% higher than that of no alcohol involvement. As a consequence, the risk of USAF drivers to die or suffer PT or PPT disability is dramatic when they consume alcohol and drive their cars.

In the framework of alcohol related MVCs, factors such as gender and rank, both commonly associated with drivers' alcohol consumption, seem to be statistically significant factors in the categorical data analysis.

Alcohol Involvement by Gender

It is emphasized that the AFSC data analysis reveals that most accidents are not alcohol related. However, the majority of alcohol related MVCs, involve male drivers. On the contrary, female is the predominant gender in non alcohol related MVCs. Alcohol and male gender in any given crash are significantly associated.

Alcohol Involvement by Rank

This analysis further reveals that some rank groups are more likely than others to conduct impaired driving. In particular the Airmen group is involved in the majority of alcohol related MVCs and appear to assume the greatest risk for such an event. Additionally, Senior NCOs and NCOs, display the second and third highest

risk of impaired driving. Ultimately, the least risky rank groups for driving under the influence of alcohol are Company Grade and Field Grade Officers.

Injury Class by FY

Operations tempo or work load in the USAF are represented in this study by the variable FY, as it incorporates political and major events such as the war against terrorism, deployments and other incidents that influence military life. In light of these conditions, the period FY 1988 to 2009 are divided according to war timelines in which the AF was engaged to aid in the demonstration and explanation of MVCs over the past two decades.

It is revealed that FYs related with changes in the work load and work environment are associated with the severity of a MVC, because type of injury was disproportionally distributed during these periods of time. In particular, the time from FY 2001 to FY 2004, when the US and Coalition Forces invaded Afghanistan and Iraq to fight terrorism, is related to higher number of fatal accidents as compared to any other period of high operations tempo. Similarly, service members faced extensive involvement in permanent partial and total disability MVCs.

However, during the period FY 2005-2009 when the USAF was still involved in war vs. Iraq and Afghanistan, the proportion of fatal MVCs was lower than in the early stages of the war. On the contrary, during this same time, the risk involvement in permanent partial disability types of MVCs is higher than the early stage of the war, while drivers experienced lower risk for permanent total disabilities due to MVCs.

These rates provide pertinent information about how diversities in operations tempo and work load during the same event are related to the severity of MVCs. The US invasion of Panama and Persian Gulf War FY 1989-1991, show the second

highest involvement in fatal MVCs. In addition, in FY 1995-1996, when the US was engaged with NATO as peacekeepers in former Yugoslavia, results show the lowest involvement in fatal accidents even though this period was the riskiest. In fact, even though the proportion of severe MVCs is very low, the driver experiences the highest risk to die or to sustain PP disability.

In conclusion, the most risky period is during FY 1995-1996 which means that from all MVCs occurred at that period the likelihood to be fatal was higher than any other period. The second risky period is 2004-2005, followed by 1989-1991 and 2001-2004.

The previous discussion of whether high or low operations tempo influences MVCs reveals that the majority of fatal MVCs as well as P.P -T. Disability accidents occur during periods with high operations tempo. However the most risky period is during peacetime, and as a consequence, low work load because the fatal proportion of all MVCs occurring during that time is higher than the fatal proportion of all MVCs during wartime. Data relative to deployments or the proportion of deployed personnel is not provided. However, inferences for high or low operations tempo can be made because, apart from deployed personnel, service members who remain feel pressure because the AF task must be accomplished with even less personnel.

Alcohol Involvement by FY

As stated earlier, the majority of MVCs are not alcohol related and they are not uniformly distributed according to FY. In particular, during the early stage of wars in Iraq-Afghanistan, the risk of impaired driving was the highest following the Gulf War, Iraq-Afghanistan (2005-2009), and, finally the period of US as part of the NATO acted peacekeeping force in former Yugoslavia. As a consequence, the study

found that alcohol and changes in the work environment are both associated with and influence MVCs involving USAF personnel.

Rank by FY

This thesis revealed that the majority of MVCs that occur during stressful operations tempo involve the Airmen and NCO rank groups. However, the influence of events and change in the work environment varies for each rank group. In particular, Field Grade Officers are most affected by FYs with high operations tempo as indicated by the high proportion of MVCs. The second group most significantly influenced was NCOs followed by Company Grade Officers and Senior NCOs. Interestingly enough, the group least influenced by fluctuations in the pace of operations was the Airman group. In fact, this is the only rank group that demonstrated smaller diversity in road traffic risk between these periods.

Multiple Regression Results

As stated previously in Chapter III, the specification for a statistical model that sufficiently portrays real world activities is a delicate and complicated task. Besides, no simple model can completely describe the characteristics and determinants of a process and their relative outcomes (Newbold et al, 2010).

The technique employed by this thesis for model building is based on adequate modeling of the underlying process for the research question of interest. Through a comprehensive process that exercises every valid source, this thesis concludes with a three-variable model described in detail in Chapter IV. All the variables are continuous and the model demonstrates an R-Square (adj) 0.992% that meets the OLS assumptions. However, because it uses the entire database, validation cannot be applied.

Specifically, the model has significant main factors which are male gender, age (31-35), and FY. Studentized Betas, indicate the dominant variable is male gender, while age (31-35) and FY appear to be influential as well, in terms of operations tempo. It is well known that national and political issues play significant roles regarding operations tempo, which may cause fluctuations in private MVC trends. The effort of this thesis was to capture these ripples with respect to specific time periods, while recognizing the implicit deficiency of the analysis due to the short 22 year time period (FY 1988 – FY 2009). Future research could decrease the weaknesses and limitations of the data base by incorporating a longer period of time.

Recommendations for Future Research

This thesis expanded previous research and established the basis for future research. Indeed, future research with additional data (FY), as well as supplementary information such as vehicle speed could be valuable contributions for testing the influence of operations tempo.

Severity and frequency of MVCs are major cost drivers. However, this study could not expand the research due to incomplete data with respect to cost. Provided the availability of relative total injury cost data, future analysis of the finance burden of private MVCs would be realized.

In addition, another potential area for research would be whether USAF safety intervention programs are effective. For example, research could evaluate whether safety campaigns such as the '101 Critical Days of Summer' truly make a difference or if other intervention programs return better results.

Appendix A. Definitions of Economic Costs

Medical Costs:

The cost of all medical treatment associated with motor vehicle injuries including that given during ambulance transport. Medical costs include emergency room and inpatient costs, follow-up visits, physical therapy, rehabilitation, prescriptions, prosthetic devices, and home modifications.

Emergency Services:

Police and fire department response costs.

Vocational Rehabilitation:

The cost of job or career retraining required as a result of disability caused by motor vehicle injuries

Market Productivity:

The present discounted value of the lost wages and benefits over the victim's remaining life span.

Household Productivity:

The present value of lost productive household activity, valued at the market price for hiring a person to accomplish the same tasks.

Insurance Administration:

The administrative costs associated with processing insurance claims resulting from motor vehicle crashes and defense attorney costs.

Workplace Costs:

The costs of workplace disruption that is due to the loss or absence of an employee. This includes the cost of retraining new employees, overtime required to

accomplish work of the injured employee, and the administrative costs of processing personnel changes.

Legal Costs:

The legal fees and court costs associated with civil litigation resulting from traffic crashes.

Travel Delay:

The value of travel time delay for persons who are not involved in traffic crashes, but who are delayed in the resulting traffic congestion from these crashes.

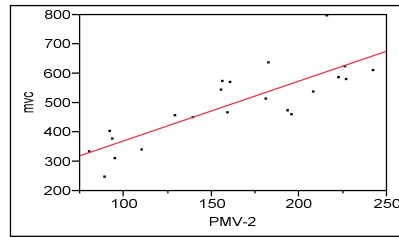
Property Damage:

The value of vehicles, cargo, roadways and other items are damaged in traffic crashes.

(NHTSA, 2002: 73-74).

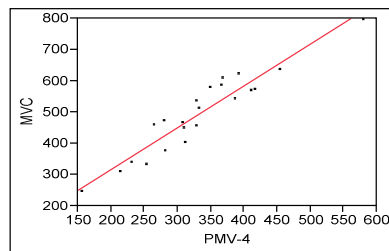
Appendix B. Actual by Predicted Plots

Bivariate Fit of MVC By PMV-2



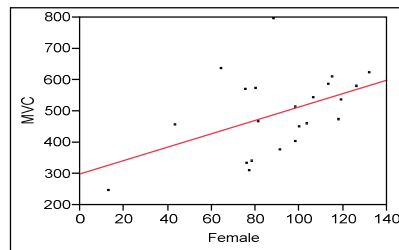
RSquare (Adj): 0.667, P-Value <0.0001

Bivariate Fit of MVC By PMV-4



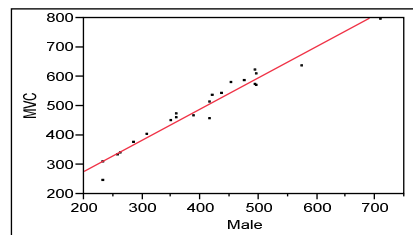
RSquare (Adi): 0.883, P-Value <0.0001

Bivariate Fit of MVC By Female



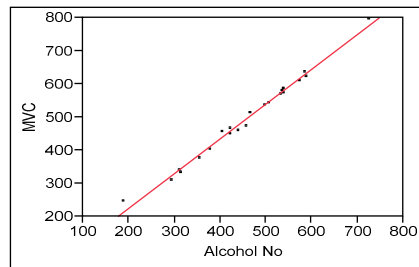
RSquare (Adi): 0.176, P-Value =0.0296

Bivariate Fit of MVC By Male



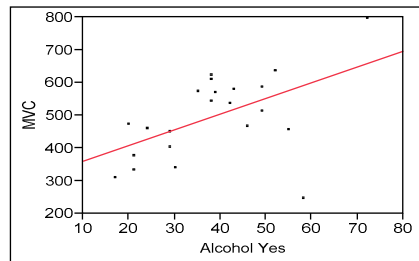
RSquare (Adi): 0.954, P-Value <0.0001

Bivariate Fit of MVC By Alcohol No



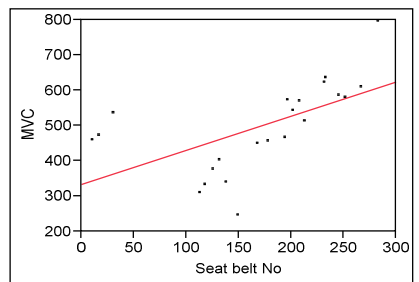
RSquare (Adi): 0.989, P-Value <0.0001

Bivariate Fit of MVC By Alcohol Yes



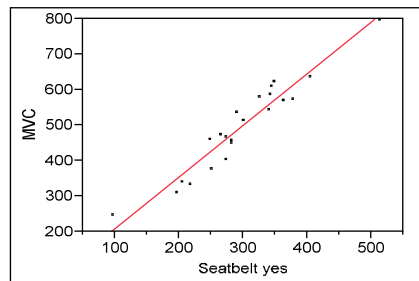
RSquare (Adi): 0.277, P-Value =0.0118

Bivariate Fit of MVC By Seat belt No



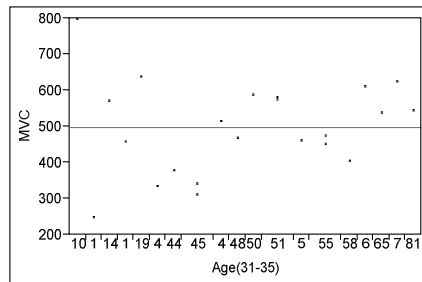
RSquare (Adi): 0.308, P-Value =0.0043

Bivariate Fit of MVC By Seatbelt yes



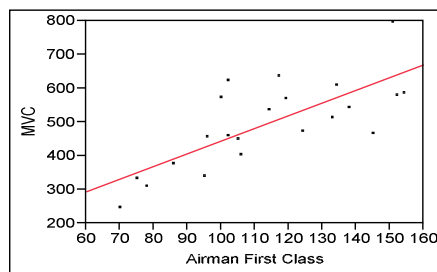
RSquare (Adi): 0.915, P-Value <0.0001

Oneway Analysis of MVC By Age(31-35)



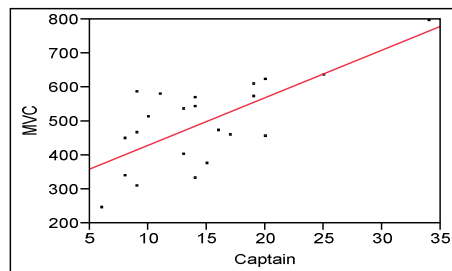
RSquare (Adj): 0.983, P-Value <0.0025

Bivariate Fit of MVC By Airman First Class



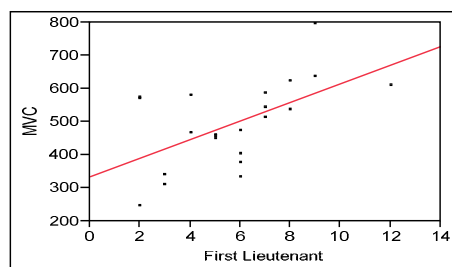
RSquare (Adi): 0.5320, P-Value <0.0001

Bivariate Fit of MVC By Captain



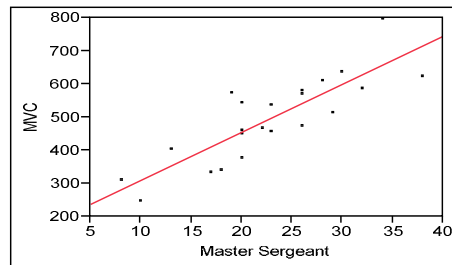
RSquare (Adi): 0.472, P-Value =0.0002

Bivariate Fit of MVC By First Lieutenant



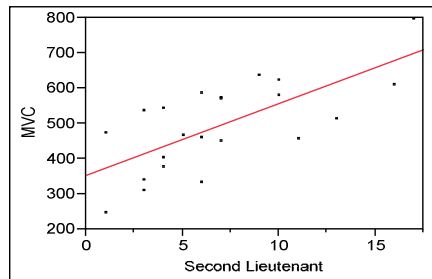
RSquare(Adi): 0.2831, P-Value =0.0063

Bivariate Fit of MVC By Master Sergeant



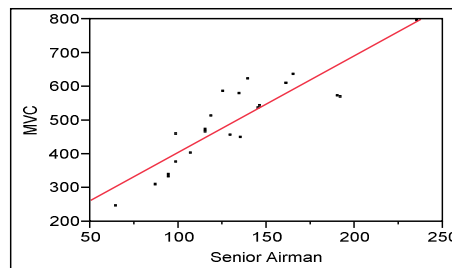
RSquare (Adi): 0.6986, P-Value <0.0001

Bivariate Fit of MVC By Second Lieutenant



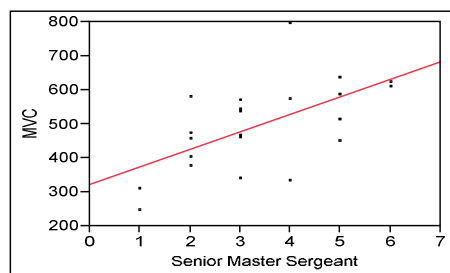
RSquare (Adi): 0.470, P-Value =0.0003

Bivariate Fit of MVC By Senior Airman



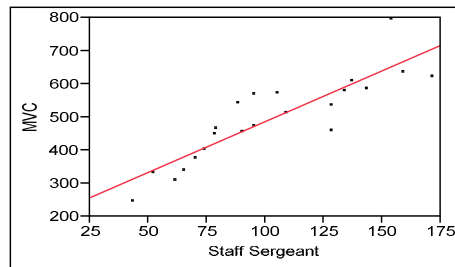
RSquare (Adi): 0.771, P-Value <0.0001

Bivariate Fit of MVC By Senior Master Sergeant



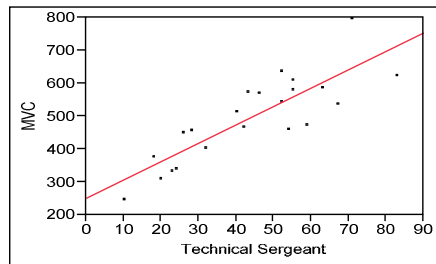
RSquare (Adi): 0.325, P-Value=0.0033

Bivariate Fit of MVC By Staff Sergeant



RSquare(Adi): 0.762, P-Value<0.0001

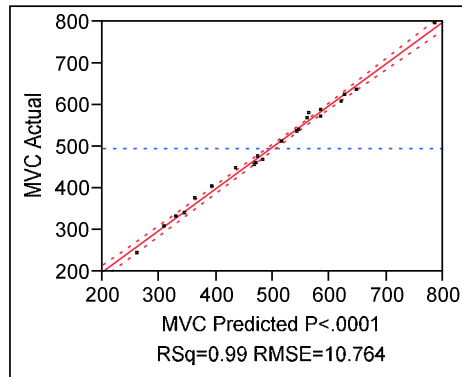
Bivariate Fit of MVC By Technical Sergeant



RSquare(Adi): 0.699, P-Value<0.0

Appendix C. Whole Model

Whole Model Actual by Predicted Plot



Summary of Fit

RSquare	0.99398
RSquare Adj	0.992977
Root Mean Square Error	10.76382
Mean of Response	495.1818
Observations (or Sum Wgts)	22

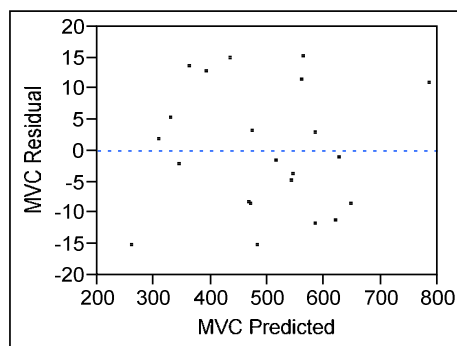
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	344345.79	114782	990.6959
Error	18	2085.48	116	
C. Total	21	346431.27		
				Prob > F <.0001*

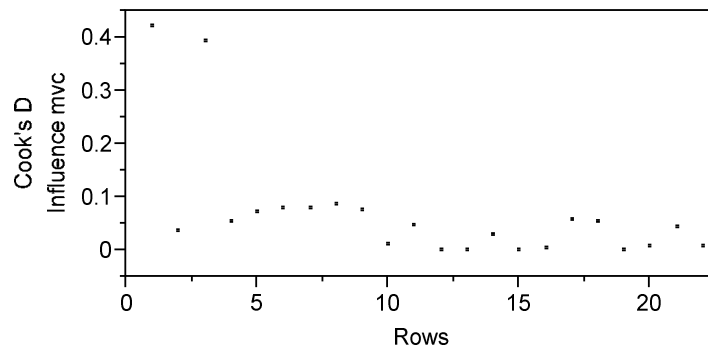
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	-4.002055	10.77289	-0.37	0.7146
Male	1.0956288	0.020136	54.41	<.0001*
31-35	0.7111171	0.161999	4.39	0.0004*
FY	2.0743477	0.488847	4.24	0.0005*

Residual by Predicted Plot



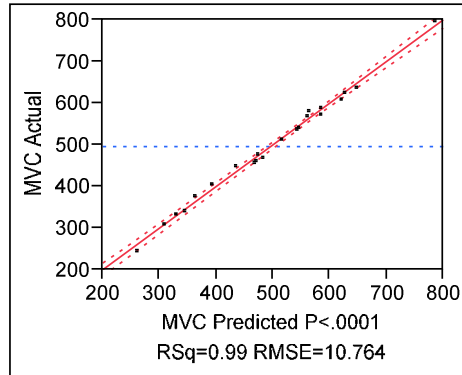
Overlay Plot



Appendix D. Whole Model without Cook's Distance Data

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.99398
RSquare Adj	0.992977
Root Mean Square Error	10.76382
Mean of Response	495.1818
Observations (or Sum Wgts)	22

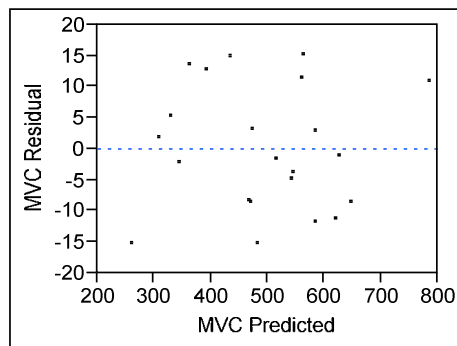
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	344345.79	114782	990.6959
Error	18	2085.48	116	
C. Total	21	346431.27		
				Prob > F <.0001*

Parameter Estimates

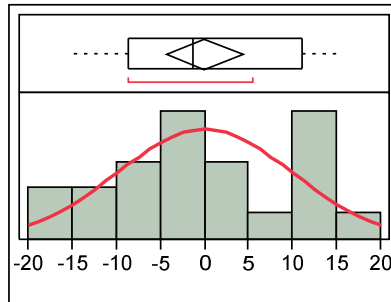
Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	-4.002055	10.77289	-0.37	0.7146
FY	2.0743477	0.488847	4.24	0.0005*
Male	1.0956288	0.020136	54.41	<.0001*
31-35	0.7111171	0.161999	4.39	0.0004*

Residual by Predicted Plot



Appendix E. Diagnostics Tests

Residual mvc



Normal(-2e-14,9.96536)

Quantiles

100.0%	maximum	15.15
99.5%		15.15
97.5%		15.15
90.0%		14.54
75.0%	quartile	11.06
50.0%	median	-1.33
25.0%	quartile	-8.51
10.0%		-14.18
2.5%		-15.18
0.5%		-15.18
0.0%	minimum	-15.18

Moments

Mean	-1.55e-14
Std Dev	9.9653644
Std Err Mean	2.1246228
Upper 95% Mean	4.4183951
Lower 95% Mean	-4.418395
N	22

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	-1.55e-14	-4.418395	4.4183951
Dispersion	σ	9.9653644	7.6668666	14.24115

-2log(Likelihood) = 162.594378413684

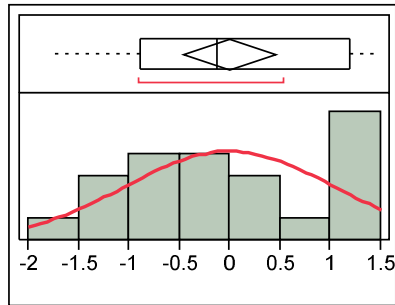
Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.936900	0.1708

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

Studentized Resid mvc



Normal(-0.0068,1.03142)

Quantiles

100.0%	maximum	1.488
99.5%		1.488
97.5%		1.488
90.0%		1.450
75.0%	quartile	1.192
50.0%	median	-0.131
25.0%	quartile	-0.878
10.0%		-1.379
2.5%		-1.753
0.5%		-1.753
0.0%	minimum	-1.753

Moments

Mean	-0.006796
Std Dev	1.0314224
Std Err Mean	0.2199
Upper 95% Mean	0.4505114
Lower 95% Mean	-0.464103
N	22

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	-0.006796	-0.464103	0.4505114
Dispersion	σ	1.0314224	0.7935262	1.4739694

-2log(Likelihood) = 62.7946051409171

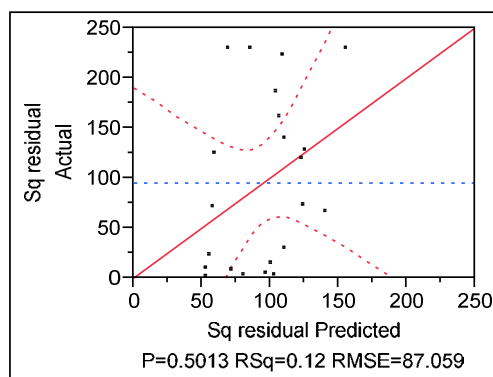
Goodness-of-Fit Test

Shapiro-Wilk W Test

W	Prob<W
0.935716	0.1614

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

Whole Model Actual by Predicted Plot



Summary of Fit

RSquare	0.119831
RSquare Adj	-0.02686
Root Mean Square Error	87.05895
Mean of Response	94.79447
Observations (or Sum Wgts)	22

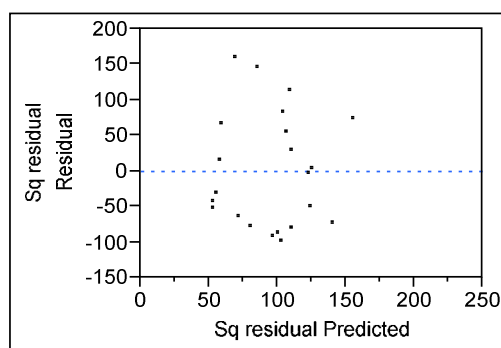
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	18573.91	6191.30	0.8169
Error	18	136426.70	7579.26	Prob > F
C. Total	21	155000.61		0.5013

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	175.07852	87.1323	2.01	0.0597
FY	-3.960872	3.953849	-1.00	0.3297
Male	-0.053088	0.162864	-0.33	0.7482
31-35	-0.29372	1.310263	-0.22	0.8252

Residual by Predicted Plot



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Vita

Major Ilias Kesisiklis, an officer in the Hellenic Air Force, was born in Serres, Greece. He graduated from the Lyceum in Iraklia-Serres, Greece, received a Bachelor in Economics from the University of Macedonia in Thessalonica, Greece in 1991 and enrolled in the Hellenic Officers Military Academy in 1993.

He was assigned to the Hellenic Air Force/112 Combat Wing Air Force Base at Eleusina, Greece as Procurement and Finance Officer until 1998 and until 2002 assigned to the 128 Squadron in Athens, Greece with the following duties:

- a. 1998 to 2001, Accounting and Finance Officer
- b. 2001 to 2002, Financial Controller

From 2002 to 2005, he was assigned to the Hellenic Air Force General Staff, Directorate D3/3/3c as Chief of the NATO Budget office, related to Greece, serving as the Hellenic representative in the following NATO Committees and programs:

- a. NATO AWACS Programme Management Organization/ Legal Contract and Finance Committee (NAPMO/LCF).
- b. Air Defence Ground (ADG), Working Group.
- c. RFAS Programme, Finance Committee
- d. JUPCC Programme, Finance Committee
- e. OPEN SCIES Programme, Finance Committee

Concurrently, he was the Finance Director of the Forward Operating Base (FOB), Aktion Greece.

Major Kesisiklis was assigned to 135 Squadron, Skiros Greece as the Financial Controller From 2005 to 2007 and, through August 2009, was the Financial Controller for M.GEA, Air Force General Staff Support Unit..

In September of 2009, he entered the Cost Analysis Master's Program at the Air Force Institute of Technology's School of Engineering and Management at Wright Patterson Air Force Base, in Dayton Ohio. Upon graduation, he will be assigned to the Hellenic Air Force General Staff.

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